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Minutes of TOPEX/POSEIDON Science Working Team Meeting and Ocean Tides Workshop

December 1994

Lee-Lueng Fu
Editor

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Prepared for

National Aeronautics and Space Administration
and

Centre National d'Etudes Spatiales
by

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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General Summary

A TOPEX/POSEIDON Science Working Team (SWT) meeting was held on 4 December 1994, the day before the American Geophysical Union (AGU) Fall Meeting, at the Cathedral Hill Hotel, San Francisco. The primary objective of the meeting was to review the status of the Project, in particular the revision of tide models, precision orbits, and various science algorithms, based on analysis of the mission data collected to date. Nearly 70 papers on scientific results from the mission were presented in a 2-day Union Session in the AGU Fall Meeting that followed.

The SWT meeting was preceded by a workshop on ocean tides, held on 3 December 1994, also at the Cathedral Hill Hotel. The workshop was convened by Christian Le Provost, C-K. Shum, and Phil Woodworth. The purpose of the workshop was to review all the ocean tide models developed for applications to TOPEX/POSEIDON, and make recommendations to the Project on which models to be included in the geophysical data records.

This report was compiled from notes taken by Roger Davidson, with inputs from most of the speakers. The coverage of the meetings may not be complete. Copies of the viewgraphs presented in the SWT meeting are included in an appendix for detailed reference. Also included as appendixes are both meeting agendas, the attendance lists, a list of the abstracts presented in the AGU Meeting, and a list of the titles of papers submitted to the second JGR TOPEX/POSEIDON special issue.

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Minutes of the Science Working Team Meeting
4 December 1994

Lee-Lueng Fu, NASA Project Scientist, opened this third Science Working Team Meeting with a welcome to the almost 100 attendees. He then introduced Charles Yamarone, who summarized performance of the TOPEX/POSEIDON to date.

Charles Yamarone, NASA Project Manager, on current TOPEX/POSEIDON Project status.

TOPEX/POSEIDON has had essentially nominal operations for the first 25 months of operations. It is presently in orbital cycle 82, having completed 10,832 orbits of the Earth.

An enhanced outreach program is currently under development.

Mr. Yamarone introduced Joseph Bishop, the new Program Manager. Mike Van Woert has been replaced by Miriam Baltec, Chief of the Oceans, Solid Earth and Natural Hazards Branch of Mission to Planet Earth as the Program Scientist for TOPEX/POSEIDON .

At present 99% of all possible data has been obtained. GDR production remains on schedule with product being shipped through Cycle 76. The current measurement accuracy is 4.7 cm and the orbit has been maintained within the ±1 km band. Seven orbit maintenance maneuvers have been accomplished between cycles and over land to minimize data effects.

The effects of single-event upsets (SEUs) on the satellite have been minimized. Phil Callahan distributes a full report regularly to the SWT members.

Navigation remains nominal despite the ASTRA1-B star tracker remaining off line. The second star tracker, along with the substitute digital fine sun sensor, have performed well. The Earth Sensor Assembly (ESA) is of the same design as some that have failed on other satellites. TOPEX/POSEIDON ESAs have not shown any failure symptoms and are only used for recovery from safehold conditions. The Project is developing a software alternative to using these sensors to come out of a safehold condition, so that we can do the extended mission more confidently.

In the power system, the solar array continues to perform with degradation no greater than that predicted before launch. Our analysis shows that full power will be available for 7.2 years of lifetime. The batteries are performing evenly and consistently. The conservative battery charge/discharge management, called TLC (tender loving care), continues to be successful.

The NASA Altimeter is performing well and has recovered from SEUs autonomously for 39 of 47 occurrences. Other onboard instruments are also performing as expected. The Global Positioning System (GPS) Demonstration Receiver is giving excellent results and may have Code O support for doing antispoofing orbits for 12 consecutive orbits; however, this will require the support and recommendation of the science team. Regardless, there will be other episodes of antispoofing in the next six months.

The satellite command error rate is falling and is now near 0.2% cumulative. The extended mission will begin at the end of September 1995 for a period of 3 years at greatly reduced funding levels. Project Operating Plans are to be developed by mid-March 1995. This reduction will affect both operations and science funding.

Philippe Escudier, CNES Project Manager, on CNES Status.

The satellite has enjoyed nominal operations, and the SSALT altimeter was turned on about one cycle in every ten. Production and distribution of data products remain on schedule. Auxiliary products such as the tide models are also available. CNES is maintaining a high level of expertise to plan for future missions.

DORIS has had some SEUs, but they have resulted in no discontinuity on the POD product. CNES has begun beacon replacement this year, and is looking at augmenting network density. A new receiver is under development that will begin working with ENVISAT. It has better receiver characteristics and should also be more resistant to SEUs.

The CNES solid-state altimeter (SSALT) is an experimental sensor, which nevertheless has met all requirements and its data can be merged with TOPEX data. The SSALT Team is currently working with onboard software improvements to reduce noise level and help tracker bias. The extended mission will include multimission operations and should not be a problem.

Lee-Lueng Fu, NASA Project Scientist, on the program status, some science issues, and future events of concern to the Science Working Team.

The first TOPEX/POSEIDON special issue by the JGR contains mostly validation and engineering papers. The next special issue should contain more science results. Investigators are encouraged to publish in more popular publications like Science and Nature.
Some obvious topics for future articles would be the tide model, global mean sea level, seasonal cycles, comparison with numerical models, and the ENSO prediction. The current submission deadline for the second JGR is 1 February 1995. Ten papers have already been submitted. We anticipate that the bulk of papers presented in the TOPEX/POSEIDON AGU special sessions will be submitted for publication.

We are now reaching the prime part of the mission, and the quality and amount of data should generate sufficient interest for more frequent science meetings. We also plan to enhance coordination and efficiency in publications and outreach activities. Semiannual SWT meetings are desired. A midyear SWT is scheduled at JPL for 5/10/1995. In the meantime, we should improve communication between investigators, and enhance and expand the Mosaic home pages as a communication tool.

The plans for science during the extended mission are to have a performance review of each PI team to determine their funding level for the extended mission. The Project will review publications, the effectiveness of meeting proposed objectives, and the teams' science plan for the extended mission. Team restructuring for the extended mission phase is encouraged.

Yves Menard, CNES Project Scientist, on an upcoming oceanography meeting.

The next oceanography meeting in France is planned for 16-20 October 1995. The proposed title is Observational Oceanography and Space Operations, with SMF and CNES joint sponsorship. The scientific committee is being formed and several TOPEX/POSEIDON PIs will be asked to join it. The major scientific topics will be:

Oceanographic application and space data requirements

Observation systems for operational oceanography

Assimilation of data into models

Socio-economic impact

The first day will be devoted to the TOPEX/POSEIDON SWT, and the remaining days will be devoted to a plenary session, followed by a poster session. French-English translation will be provided. The conference will be held in Biarritz at the Casino de Biarritz. A call for papers will be sent out this December. The abstract deadline is 15 June 1995 and paper acceptance by 15 September.

Edward Christensen, NASA Deputy Project Scientist, Science System Manager, and Manager of NASA outreach efforts.

The TOPEX/POSEIDON outreach program is currently under development and will have the following components:

Public information

Educational outreach to inspire an interest in science among K–6th graders, enhance the science curriculum of junior and high school students, and facilitate college educational opportunities

Technology commercialization

The outreach program will aim to inform the public within the context of global change and Earth remote sensing from space.

NASA is putting together an outreach team with both project external and internal members. (This includes all SWT members.) The outreach program cornerstones will be computer multimedia products such as a Mosaic home page, CD-ROMs for education, video products, curriculum development and involvement (the weakest area at the moment), and articles for the news media.

The Mosaic home page is http://topex-www.jpl.nasa.gov. We will continue to develop home pages, and will provide links via the TOPEX/POSEIDON home page. SWT members and project personnel are encouraged to make presentations to public schools, universities, public societies, and clubs. We are looking for contributions to computer multimedia, video and curriculum product development. It is our intent to encourage the reporting of significant scientific results to the news media and to publish articles in more mainstream periodicals

Patrick Vincent, on CNES outreach efforts.

Until recently, public outreach has been accomplished through seminars, meetings, newsletters and summer schools. Our current World-Wide Web home page is http://192.134.216.41 A prototype information server is currently under development. It will be updated regularly with new results. The prototype should allow an electronic forum, access to AVISO products, and FTP access to selected products. We hope to be on line by June 1995. If the Project provides any Mosaic home page development tools, maybe it could provide a standard home page template and an example. Any outreach effort should include public domain CD-ROMs as an alternative for those who do not have Internet access.

Francois Nouel on CNES Precision Orbit Determination Status.

DORIS data coverage is 77–83% of beacon availability. We presently use short arc checks for comparison, and there is not a large difference now between CNES and JPL POD. CNES will replace 7 beacons per year and extend the DORIS network with 10 more beacons. ZOOM software will go to a Sun UNIX system in 1996. DORIS is under probationary phase at International Earth Rotation Service. CNES is also presently investigating solar activity parameters and is working on reduced dynamic orbit for DORIS measurements. DORIS will provide 5-m, real-time, onboard tidal calculations; a 50-cm orbit error in one day; a 10-cm error within one cycle; and a 5-cm error within two cycles.

Byron Tapley, University of Texas at Austin, on gravity models and precision orbit determination.

The JGM-3 gravity model incorporates GPS data and it uses more DORIS and SLR data as well as Lageos-1, and -2, Spot-2, and Stella data. The differences between JGM 3 and 2 may manifest themselves as differences of up to 4 cm in some areas. Changes in the gravity field affect the mean difference the most, while the new tidal model has more effect on the variability results. The new UT Center for Space Research and JPL GPS-reduced dynamical orbits compare to less than 2 cm for cycles 43 to 50. There is also a Z-offset between the orbits, which should be removed for comparison. In conclusion, the new model has accuracy better than 3 cm radially. An orbit accuracy of better than 2 cm in the TOPEX/POSEIDON lifetime is a reasonable goal. We would like DoD to turn off antispoofing one 10-day period each month, commensurate with a TOPEX/POSEIDON cycle through the end of mission, but will need SWT recommendation to accomplish this policy.

Are there plans to reprocess the orbits from the start of the mission? Once the JGM 3 model is approved and tested; reprocessing is not that difficult.

The following position was adopted by the SWT:

> It is recommended that the Department of Defense periodically turn off GPS antispoofing (AS) for at least one 10-day period each month commensurate with defined TOPEX/POSEIDON 10-day repeat cycles, for the duration of the mission. This request is justified because a reduction on 1–2 cm in the RMS mean sea surface error introduced by SLR and DORIS orbits may be achievable through improvements in the dynamic models and the orbit determination strategies afforded by GPS data analysis. The reduction of sea surface measurement error would contribute significantly to global ocean circulation modeling, and to analyses of the temporal variability of the ocean surface.

Philip Callahan, NASA Measurement Engineer, on NASA altimeter bias and drift.

The new sigma0 calibration is now available. It is documented in the TOPEX/POSEIDON Research News. The new values can change the EM bias correction by about 2 mm.

Bruce Haines on Platform Harvest Verification Campaign status.

There have been 81 overflights to date (68 ALT, 12 SSALT and 1 safehold). Extensive evaluation of cycles 2–36 has been done, with extended analysis through Cycle 75. The nominal strategy uses the NOAA acoustic tide gauge, new JGM-3 orbits from GSFC, as well as the GDR

and Gaspar3 parameter sea-state bias models for ALT and SSALT. Biases with standard (noise-only) error estimates are:

ALT mean -13.8 ±0.3 cm, slope 0.1 ±0.6 cm/year

SSALT mean 0.1 ±0.8 cm, slope -2.0 ±1.7 cm/year

Biases with error estimates that account for systematics (e.g., platform position uncertainty, etc.):

ALT mean -13.8 ±3.0 cm, slope 0.1 ±1.0 cm/year

SSALT mean 0.1 +±3.0 cm, slope -2.0 ±2.0 cm/year

A negative sign implies that the ALT is measuring short. Repeatability of the bias measurements is about 2 cm.

Global crossover analysis results are based on the new JGM-3 orbits and the Ray et al. tide model. Using a nominal approach, the relative bias estimate is 14.6 cm. Cycle-to-cycle repeatability is about 0.5 cm. Differences in the sea state bias/ion models impact relative bias at the 1–2 cm level.

It was also stated at the SWT that TOPEX/POSEIDON has an onboard drift correction, and should have no drift.

Yves Menard, CNES Project Scientist, on the CNES verification effort.

The present ionospheric correction RMS difference is 1 cm. The sea-state bias correction was done using Gaspar4. The instrument biases are as follows:

ALT -18.5 cm ±3.4 cm

SSALT +1.0 ±2.4 cm

ALT (with shared data) -14.7 ±2.1 cm

GPS buoy results are slightly less optimistic. CNES will try to get a new calibration site at Capraia, Italy.

Dr. Pierre-Yves Le Traon on the relative altimeter measurement bias.

The comparison used Gaspar4 model for POSEIDON and TOPEX. The repeat track and crossover analyses result in a bias of 15.5 ± 0.5 cm.

George Hayne, NASA, on the NASA Altimeter bias drift.

The altimeter uses internal onboard calibration for range measurement. In over 80 cycles we see a drift from +2 to -3 mm. Various other measurements and design implementations make reporting to this accuracy very difficult.

Steve Nerem, NASA Goddard Space Flight Center, on mean sea level variation and new gravity models.

Sigma0 does make a difference in the measurement of sea level when investigating global sea level rise. We will need longer periods of time using calibration with in situ data until the error estimate drops below the level we are investigating or expecting for global sea level rise. The uncalibrated estimate of sea level rise is around 5–6 mm/year, and an average calibration of about 2 mm/year for other drifts gives a rise rate of 3 mm/year. These estimates are affected by the type of inverse barometer correction.

There is evidence that data from the first 8 cycles are anomalous. The new estimate of sea level rise rate with various corrections is 2.9 ±1.2 mm/year.

JGM-3 has reduced the gravity error to less than 1 cm. JGM-3 (70 x 70) is an augmentation of JGM-2 and includes many data sets, including the GPS data, which was not in JGM-1 and 2. OSU91A is a 360 x 360 model and is therefore useful for short-wavelength gravity effects. There is a banding structure in differences between JGM-2 and 3, and between JGM-2 and the OSU model. JGM-3 is recommended over JGM-2 for geoid uses, but there still are significant differences from the oceanographic data in the Pacific.

GSFC will be producing a 360 x 360 gravity model with the Defense Mapping Agency (DMA) to be out in 1996. Improvements may also come out of the new GPS receivers that will be flown on new satellites. We can get a full error covariance matrix for JGM-3. Some people already have it.

Jean-Michel Lemoine on the GRIM4 and S4/C4 gravity field models.

Final improvements will take at least one year. The S4 model is satellite data up to degree 69. The C4 model combines surface data and S4, complete up to degree 72. Over-ocean agreement with JGM-3 is about 31 cm, but there are large differences over continents with an RMS of 1.28 m. (Different data sets exist for all continents but North America.) This model and Cazenave 94 mean sea surface and geoid compare to about 27.5 cm, with most of the differences at the north pole. The GRIM4-C4 model shows less spectral power beyond degree 60; this is believed to be due to the use of satellite data only near the poles, which have less spectral power in this range. The GRIM4 - S4 and C4 models perform similarly when tested with crossover differences using several satellites. The performance of JGM-3 is much closer to the GRIM4 models than is JGM-2 (testing was performed with 5-day arcs). A model is available from biancale@mfh.cnes.fr or lemoine@sc2000.cnes.fr

Ouan-zan Zanife on SSALT accuracy (bias, drift, and EM bias).

SSALT monitoring is performed by two internal calibration modes, and three calibration sequences are done each day of operation. The results after 2 years of data are that the altimeter has an internal delay variation of 3 mm during this period, and total power has a variation of 0.1 dB during this period. The goal is to reduce the noise level of SSALT. Modifications have been made to the coefficients used by the tracker and retracking software, but there was no modification of the code itself.

The onboard software was changed during Cycle 41 and again in Cycle 55. This appears to have dropped the noise level from 2.4 cm (Cycle 20) to 1.85 cm (Cycle 55), the test was made for 2-m significant wave height (SWH). The reduction in noise can also be seen in the spectral

domain. The SSALT EM bias is about 4.7% of SWH, compared to the TOPEX value of 2% of SWH.

By using the real version of MLE (perhaps available with a more powerful processor on TPFO) the noise level should drop to 1.65 cm; the use of BEM4 (Gaspar et al, 1994) is recommended until this modification is implemented. Making these changes will result in a SSALT EM bias of 2.7% of SWH.

In conclusion, the altimeter performance is within requirements and the noise level is decreasing with the described improvements. BEM4 is recommended for em bias correction.

Dudley Chelton on electromagnetic bias (EM).

The results from Stewart and Devalla seem to show that the bias model is good when looking at data from storms. Ernesto Rodriguez' results seem to show that a quadratic dependence on wind speed is reasonable. Chelton (collinear analysis) agrees with GDR and Gaspar (crossover analysis) results to within one sigma of Chelton's result, based upon a quadratic, wind-speed-dependent bias coefficient. Looking further, there seems to be a dependence on SWH with a trend opposite that for wind speed (since these two parameters are highly correlated). The matrices for least-squares analysis become poorly conditioned when trying to get a higher-order model, because of the correlation between the "independent" parameters.

The "best" model is BM4, which is quadratic in wind speed and linear in wave height. Results from Gaspar and Chelton for the four-parameter model are very similar, even when using two different methods of analysis (crossover and collinear, respectively). The four-parameter model does show some reduction of variance in high wind, and high sea state areas over the GDR model.

There remains an uncertainty of 1% SWH (see viewgraphs in Appendix B for additional points). The recommendations are to use the same formulation for TOPEX and POSEIDON, replace the GDR three-parameter model with a four-parameter model, and continue theoretical work to understand the physics of the sea state bias...specifically, why is there an apparent inconsistency between dependencies of the bias on wind speed and SWH?

Some comments were made on the need to investigate the possibility of formulations for different regimes of SWH and wind speed.

Comments were made by Wunsch and Glazman that the present EM bias models do not properly account for relevant physics. This is because the altimeter-reported SWH and wind do not provide the necessary information to predict EM bias with sufficient accuracy. As a result, present models suffer geographically and seasonally related systematic errors in SSH (as high as 3 cm, perhaps higher). There is a need for more sophisticated models and for better understanding of the EM bias relationship to oceanographic factors. (See Bruce Haines section on altimeter bias and drift.)

Philippe Gaspar, Jean-Francois Minster on the inverted barometer effect.

The standard approximation is fair, except for forcing periods less than two days, and also for coastal regions and marginal seas.

Published results are based on simple linear regression analysis. The results from Fu and Pihos (based on collinear differences from a mean track) indicate a latitudinal dependence for the inverse barometer (IB) effect. P. Gaspar's results show a different dependence on latitude,

especially for low latitudes (based on both crossover data and collinear differences between adjacent cycles). This difference seems to result from how the data differences were calculated: L-L. Fu used differences with a long-term mean, and so sees long-term ocean signals; while P. Gaspar's differencing eliminates signals with such long periods. An independent analysis from P. Woodworth and Ganachaud shows that the IB effect can be contaminated by annual and semiannual signals, resulting in a coefficient of lesser magnitude in the tropics than that of L-L. Fu.

P. Gaspar and Ponte now use model results to evaluate dynamical deviations from a pure IB effect; there seems to be significant dynamical response in the equatorial region. The dip in the equatorial region may be due, in part, to small orbit errors, since analysis with ERS-1 and GEOSAT show some correlation with the mission orbit error and the "dip" in the IB coefficient at the equator. (Alternative explanations were differences in the ionosphere correction and the meteorology used for the various missions.)

Don Collins, Patrick Vincent, and Federique Blanc on the status of PODAAC and AVISO.

P. Vincent stated that: AVISO is producing merged GDRs (GDR-Ms), as well as crossover point files and documentation. Several new products are coming out, including GDR-M data with different processing applied, and ERS-1 products.

New services added during 1994 included distribution of new data products on request, and installation of a Mosaic information server.

Version 0 is a working prototype with operational elements, and it now has an IMS connection to all other DAACs.

The home page is at http://seazar.jpl.nasa.gov. The first ERS-1 CDs (a collaboration with the University of Texas) should be out late this year.

Many other missions are coming up and will be supported by PODAAC. (Not all are U.S. missions.) The JPL PODAAC distributes several TOPEX/POSEIDON products and works with AVISO in the production and distribution of the merged CD-ROM. We are now defining TOPEX/POSEIDON level 3 data products which will be distributed. Reprocessing of the merged GDR is under discussion.

Victor Zlotnicki led a discussion about distribution of new products and corrections to users.

It is not clear why there is a 1-mm difference between the two merged GDRs. P. Callahan or R. Benada want to know about any discrepancies as they are found.

When PODAAC and AVISO distribute software and coefficient files (e.g., tides and orbit replacement), they also need to provide benchmark and test data to ensure the program, as implemented at the user's computer, gives the same answers as in the computer environment of the originator. Current distribution options are 1) letter, 2) letter + FTP, 3) CD-ROM and 4) new GDR. (Because if we are going to send out lots of CDs, we might as well do a new GDR.)

Sea state bias: Gaspar 4 is recommended, but the values need to be updated and P. Gaspar will provide new coefficients by end of January. This change is seen as essential for POSEIDON and important for TOPEX. The distribution method will be letter, and documentation will be

provided by Gaspar. We will just defer other decisions on corrections to defined groups and then give them a deadline.

Altimeter Bias: Le Traon is also responsible for this and the documentation. It is seen as essential. The deadline is 15 February. Distribution will be by letter.

Drift: Distribution will be by letter. Hayne is responsible for TOPEX. This is seen as "nice." The drift should be time-stamped. POSEIDON drift is in the GDR. Update frequency is TBD. The deadline is late January.

Tides: P. Woodworth, C-K. Shum and C. Le Provost will have an answer by the end of January. Distribution is by letter and FTP. Documentation will be provided by the author of the chosen model. This change is seen as essential.

Orbit: Will two orbits need to be computed or will old orbits need to be replaced with the new one once a new one is chosen? Tell L-L. Fu if you have input on this. P. Callahan wants a decision now because staff will decrease in the future and big changes will be more difficult then. New orbits will be on the CD-ROMs after some point in the future, such as March 1995, so the issue is then how to update the old CDs. A CD-ROM for a new set of orbits cannot be produced until all the old data have been provided with updated orbits so that the time series can be calculated for various research products. Orbit corrections will be made for past data as soon as they are available by letter and FTP. The new orbit will be available by 15 March. B. Tapley is responsible for this and for the documentation. This is seen as essential.

Inverse Barometric Correction: Nothing will be changed.

Retracked altimetry will not be made available to public at large. Those who want it can contact E. Rodriguez.

MSS: Improving the MSS would be nice, but it is not urgent. A few isolated locations near Pacific trenches were reported to show an apparent decimeter-level time variability of the MSS, possibly due to interpolator problems together with a single bad grid node. This is being investigated.

Geoid: S. Nerem, R. Rapp, and N. Pavlis are responsible for this, which will be JGM- 3 plus OSU91A. This is seen as important. Deadline is late January.

Discussion of when the tides should be done in relation to the orbit information. Suggestion from C-K. Shum is to move them closer together in terms of deadlines, in some way. This may require accepting new tide models which were not long enough in availability before the cutoff was made in this meeting.

Alain Ratier, CNES Program Manager, Beyond TOPEX/POSEIDON: the French proposal.

The collaboration between CNES, NASA, and the international science community is of great value, and the technical successes of the current mission are fully documented.

The requirements for future missions are: (1) use of the same orbit with the same accuracy, (2) ensure that the relevance (of these missions) to international initiatives and programs is recognized.

TPFO should be a series of operational missions with data accessible in real time to everyone. There are two TPFO phase A studies in work, with a phase B study approved and due to begin in 1995. SPOT-5 has been approved and the next new start will be TPFO.

Yves Menard, Lee-Lueng Fu, Concluding discussions

A proposal for a meeting in May has been adopted, and planning will begin with a steering group for drafting an agenda. Announcements will be made over the Internet.

The second JGR special issue deadline will be held, but will have a window of acceptance. Although, we will not have special issues in the future, we will have special reprint volumes, periodically. Going to a different journal would be difficult for various reasons, and JGR is the main vehicle for most of the papers in this area. We cannot commit to including papers from other journals in the special reprint volume, at this point.

TOPEX/POSEIDON Science Working Team
Ocean Tides Workshop Summary

Phil Woodworth, Christian LeProvost, and C-K. Shum

On 2 December the TOPEX/POSEIDON Tides Group held a meeting in San Francisco at which the new ocean tide models were introduced and compared. During the discussion, the group was asked by the project to recommend as far as possible:

(1) The best model to be used at the present time to give maximum spatial coverage, e.g., in shelf areas, Hudson Bay, etc. (The only model that satisfies this requirement at present is the Grenoble hydrodynamic model.)

(2) The best model to be used for deep ocean studies. This choice is more difficult because the several new models now available, based on TOPEX/POSEIDON data, are in general close agreement, although each of them has undesirable features in particular areas.

In the subsequent discussion, the list of models for application to item (2) above was reduced to five:

- the Desai and Wahr model
- the OSU TPXO2 model
- the Pavlis and Sanchez model (GSFC94A)
- the Ray, Sanchez, Cartwright (RSC) model
- the Texas CSR 2.0 model

Other candidate models were presented at the Workshop; however, they were either available only very recently, or had not been widely available for testing by other tidalists. Examples of these models include: (1) the adjusted Grenoble model constructed by O. Andersen by 'twisting' the Grenoble model fields to best represent TOPEX/POSEIDON data, (2) the assimilated Grenoble model that assimilates the Schrama TOPEX/POSEIDON-determined tide into the hydrodynamic model (FES 94.2) by L.F. Lyard (results of the M2 constituent were shown), (3) a preliminary version of L. Kantha's assimilated hydrodynamical model, and (4) E. Schrama's new model. In addition, planned revision of the above models (Pavlis/Sanchez, OSU, Desai/Wahr, etc.) and their near-future availability has been indicated.

As a result of discussions in San Francisco, and through subsequent e-mail dialogues between Lee Fu and others, the timetable for this "competition" is as follows:

(i) Because of constraints imposed by the Project and other practical considerations, the "deciding committee" for recommending the best tide models will be conducted in two phases. The interim phase is to select the models by January 31. The second phase is to select the best available model by May 1995 during the next TOPEX/POSEIDON SWT meeting.

(ii) The interim-phase models to be recommended will include the Grenoble hydrodynamical model for coastal ocean and extreme latitude applications. Another model will be recommended for the deep ocean from one of the 5 models identified above. These models will not be allowed to be revised to have consistency with the JGM-3 orbits. CSR 2.0 is the

only model computed using the JGM-3 orbits. Preliminary tests indicate that the JGM3-consistent tide model may perform worse if JGM-2 orbits are used.

(iii) The phase 2 selection will evaluate tide models submitted to the Committee (based on a set criteria described below) by March 15, 1995, giving approximately 2 months for them to be studied. (Although the official deadline for availability of new orbits is March 15, 1995, the orbits in the form of orbit corrections should be available sooner, upon request).

Criteria for acceptable submission of a candidate tide model is based on the following:

(i) Completeness in constituents, i.e., ≥8 harmonics or response formalism used.

(ii) Completeness in space, i.e., coverage as near to global as possible.

(vii) Full documentation and benchmark test cases.

(ix) The software module must be capable of (a) computing a tidal height prediction in terms of pure ocean tides or geocentric tides. Inclusion of long periods/modulation is an option, the evaluator may or may not choose to include them if they are not already there; and (b) computing pure ocean tides for at least the 8 major constituents.

(x) Tide models to be submitted by depositing the module/data files onto the FTP node (ftp.csr.utexas.edu/incoming) by midnight, March 15, 1994.

Evaluations will be made by Woodworth, LeProvost and Shum, and possibly by an expanded team of tidal experts currently under consideration.

Appendix A

Meeting Agendas

Appendix A.1

Agenda for TOPEX/POSEIDON Science Working Team Meeting of Sunday, 4 December 1994

8:30 – 9:00	Project Status – C. Yamarone, P. Escudier
9:00 – 9:30	SWT Issues (coordination of investigations, extended mission funding, journal publications, etc.) – L-L. Fu, Y. Menard
9:30 – 10:10	Outreach (public distribution of science data products) – E. Christensen, P. Vincent
10:10 – 10:30	Break
10:30 – 11:00	Tide workshop summary – C. Le Provost, P. Woodworth, C-K. Shum
11:00 – 11:30	New orbits and accuracies – B. Tapley, F. Nouel, A. Marshall
11:30 – 12:30	Altimeter bias and drift (including the relative bias between TOPEX and POSEIDON and sigma-0 drift) – B. Haines, Y. Menard, P.Y. Le Traon, P. Callahan, G. Hayne, S. Nerem
12:30 – 1:45	Lunch
1:45 – 2:15	New gravity models – S. Nerem, J.M. Lemoine
2:15 – 2:35	SSALT accuracy (new onboard algorithm and EM bias) – O. Zanife
2:35 – 2:55	EM Bias – D. Chelton
2:55 – 3:25	Inverted Barometer Effect – P. Gaspar, J-F. Minster
3:25 – 3:45	Break
3:45 – 4:15	Status of PO-DAAC and AVISO – D. Collins, P. Vincent, F. Blanc
4:15 – 5:00	How should we give TOPEX/POSEIDON users the new recommended and alternate corrections and new data products (tide models, EM bias, altimeter bias/drift, orbits, mean sea surface, geoid, merged TOPEX/POSEIDON-ERS1 data, etc.)? – V. Zlotnicki
5:00 – 5:20	Beyond TOPEX/POSEIDON: the French proposed strategy – A. Ratier
5:20 – 5:40	Concluding discussions –Y. Menard, L-L. Fu

Appendix A.2

Agenda for TOPEX/POSEIDON Ocean Tides Workshop of Saturday, 3 December 1995

First Session: New Models – P. L. Woodworth

- Introduction to meeting and session: P. L. Woodworth
- The Ohio State ocean tide models: R.H. Rapp
- A high resolution data-assimilating tidal model of North Indian Ocean: Lakshmi H. Kantha
- TOPEX/POSEIDON tide corrections at National Ocean Service: C. Wagner and C.K. Tai
- Global ocean tides from TOPEX, ERS-1 and GEOSAT altimetry: O.B. Andersen
- FES94.2: Global hydrodynamic solution for tidal elevations and currents: F. Lyard and C. Le Provost
- Ocean tide model derived at University of Colorado from TOPEX/POSEIDON altimetry and comparisons to some other models: S.D. Desai and J.M. Wahr
- Ocean tide model from 2 years of TOPEX/POSEIDON altimetry: R. Eanes and S. Bettadpur
- Tidal analysis of TOPEX/POSEIDON altimetry: E.J.O. Schrama
- Tidal models based on TOPEX/POSEIDON altimeter data and a Proudman function basis: B.V. Sanchez and N.K. Pavlis
- Progress report on a generalized response method applied to TOPEX/POSEIDON: R.D. Ray, B. Sanchez and D.E. Cartwright
- TPXO.2: An eight constituent inverse solution for global ocean tides: G. Egbert, A. Bennett and M. Foreman

****

Second Session: Model Comparisons – C. Le Provost

- Intercomparison of recent ocean tide models: O.B. Andersen, P.L. Woodworth and R.A. Flather
- TOPEX/POSEIDON tide model comparisons: M.E. Parke, G.H. Born and C. Tierney
- Accuracy evaluations of recent ocean tide models: C.K. Shum, X. Ma, X. Li and R. Eanes
- An evaluation of global tide models for TOPEX/POSEIDON: M.G. Schlax and D.B. Chelton
- Recent ocean tide models: Comparisons of observed and predicted sea level time series at tide gauge locations: J.M. Molines and C. Le Provost

- Acoustic tomography: A method for testing the large scale components of tide models: B. Dushaw, P. Worcester, B. Cornuelle and B. Howe

****

Third Session: Discussions – C.K. Shum

Questions for discussion include the following:

(i) Which of the batch of TOPEX/POSEIDON derived models is "best." This is not only a question of accuracy, compared to a standard set of gauges, but of completeness (i.e., for computing the total tide), documentation, plus ease and speed of software for recomputation of tidal correction terms.

(ii) Which features of analysis are similar in different TOPEX/POSEIDON models? If their accuracies are similar, does it matter which is used for altimetric corrections? If they are similar, then for consistency between subsequent oceanographic analyses, should one be recommended over others?

(iii) The Grenoble model stands out as the major current global model independent of altimetry. In which sort of analyses would one employ such an "independent" model compared to an empirical TOPEX/POSEIDON derived model?

(iv) What about applicability to other missions (e.g., ERS-1). In principle, missions should be processed with the same tide models.

(v) Present accuracies appear to be at the level of several cm (at least for M2). How will models improve by the end of the mission and beyond? How will we verify the accuracies (e.g. the use of the standard set of gauges)?

Appendix B

Viewgraph Copies from the SWT Meeting

TOPEX/POSEIDON SCIENCE WORKING TEAM

PROJECT STATUS

C. Yamarone

4 December 1994

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

PROJECT STATUS

- OVERVIEW
- SATELLITE/SENSORS PERFORMANCE
- MISSION OPERATIONS
- DATA PRODUCTS
- EXTENDED MISSION

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

OVERVIEW

- Mission Operations — Continued nominal operations for 2¼ years. Satellite, sensors and ground system have been performing well
  - Cycle 82 currently in process
  - Single event upsets continue to occur with only minor impacts

- Data products being delivered on schedule. Geophysical Data Records have been delivered through Cycle 76 to PODAAC

- Maintaining current performance levels of mission operations (people, satellite, ground system) is key Project objective

- Outreach — Strong focus on building an effective outreach program

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

SATELLITE

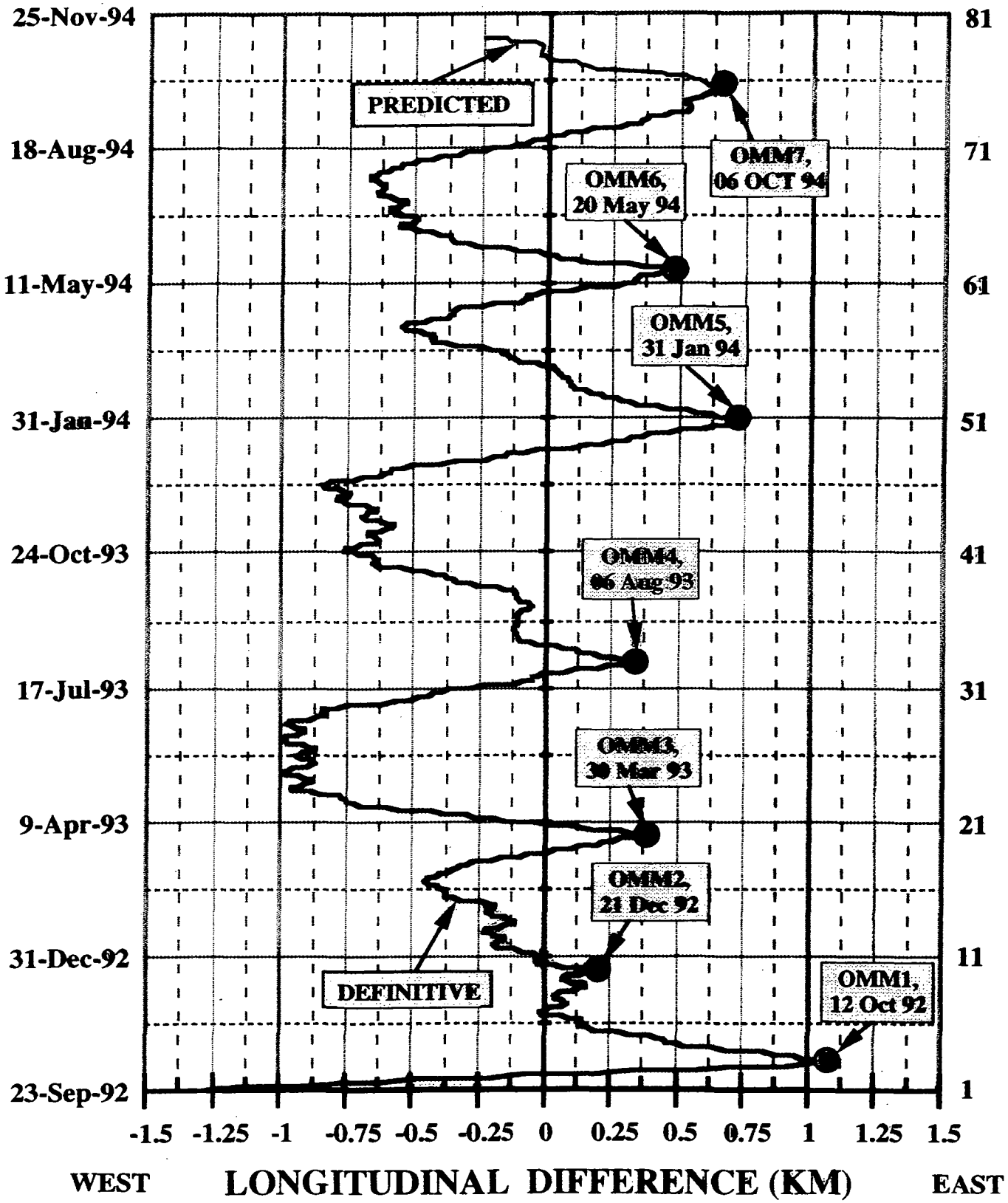
- Performance
  - 4.7 cm vs. 13 cm
  - Approximately 99% of all available ocean observations have been acquired
  - 10,832 orbits have been completed by the satellite
- Navigation
  - ±1 km repeat satellite ground track is being maintained
  - 3 orbit maintenance maneuvers have been executed since the last SWT meeting
  - Next maneuver is tentatively scheduled for April 1995 (earliest)

SATELLITE(Cont.)

- Attitude Control
  - ASTRA-1B star tracker remains in an off-line state
  - The second star tracker and digital fine sun sensor have operated adequately.
  - Earth sensors (ESA) – T/P earth sensors are of the same design as some of those that failed on other missions. To date our ESAs have not exhibited any failure symptoms and are operating nominally. Backup and contingency plans are being developed by the project

- Power System
  - Solar array continues to perform with degradation no greater than predicted before launch
  - Batteries are performing evenly and consistently – TLC measures continue to be successful

GROUND TRACK HISTORY



INSTRUMENTS

- NASA Altimeter
  - Performing well
  - SEU occurrence rate has been consistent with previous performance – recovered autonomously in 39 of 47 occurences
- CNES Altimeter (CNES)
  - Operated for cycles 55, 65, and 79
- Microwave Radiometer
  - Remains healthy and in track mode
- DORIS
  - Operating nominally
- GPS Demonstration Receiver
  - Confident of better than 3 cm radial accuracy with anti-spoofing off
  - Demonstrated 3.7 to 4.5 cm accuracy for orbits with single-frequency data

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

TOPEX/POSEIDON SEU OCCURENCES
Dec. 1993 through Nov. 1994

OPERATIONS IMPACT

	SEUs since Dec 1, 1993	Number Requiring Ground Intervention	Outage Duration
ALT	47	6	8.3 hrs, 3.7 hrs, 1.1 hrs 4.3 hrs, 2.5 hrs, 3.0 hrs
SSALT	2	2	2.1 days, 1.3 days
DORIS	2	2	1.1 days, 5.3 days
GPSDR	1	1	Still in init mode (since Nov 23)
CU	12	0	
ESAs	920	0	
ASTRA-1B	1	0	

MISSION OPERATIONS

- Successfully transitioned from NASCOM dedicated circuits to a set of multiplexed channels provided by the FTS 2000 service known as NASCOM 2000. The new circuits are land based and should provide more overall reliability

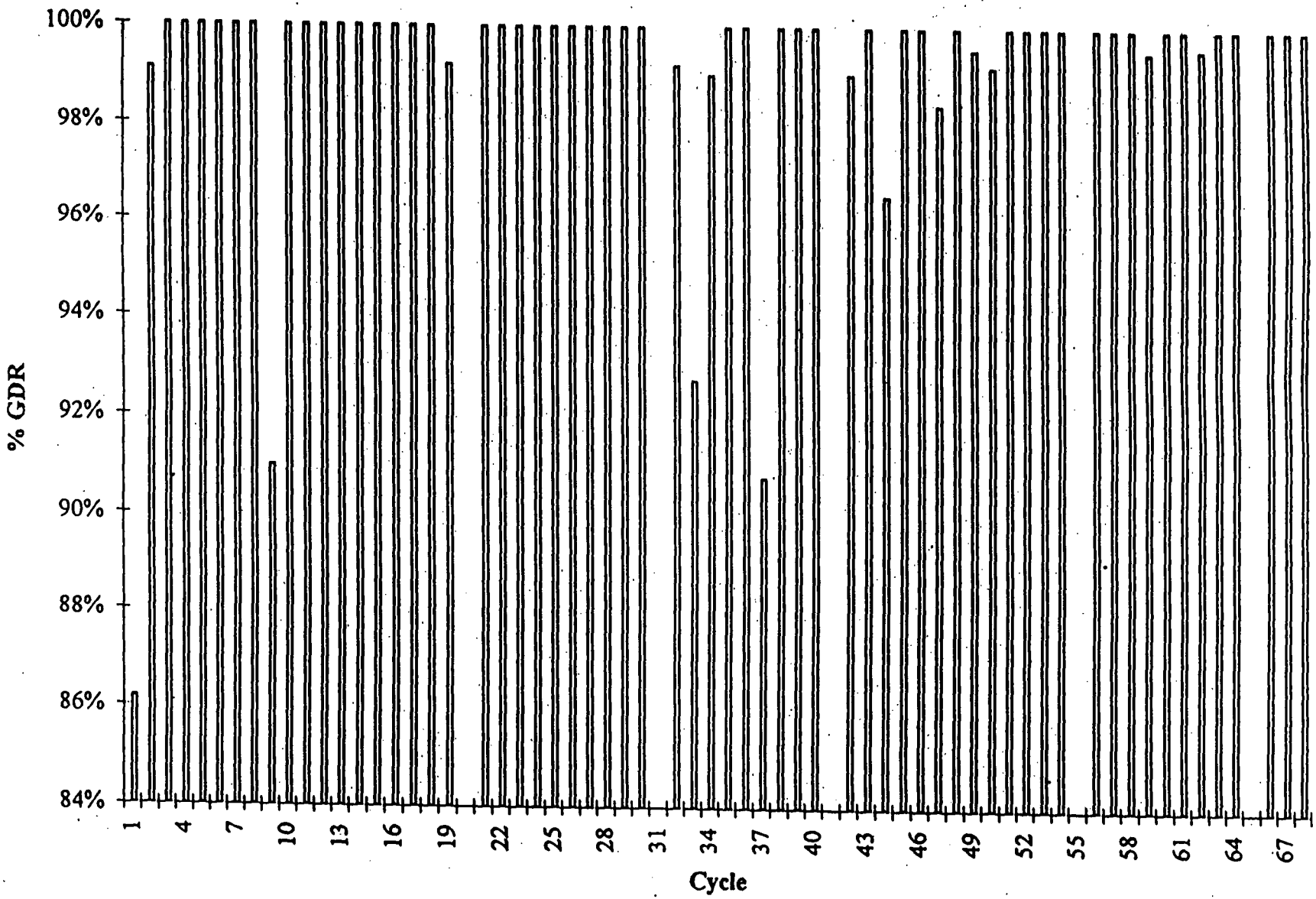
- Space Network support via the new Second TDRSS Ground Terminal has been successfully demonstrated. Approximately one-half of each days satellite contacts use the new ground station.

  Improved operations and ground processing software
  - Designed and implemented TDRSS select strategy to increase lifetime of high gain antenna gimbals
  - Ongoing development of flight software and operations strategies to safeguard the satellite and ensure prompt recognition and resolution of anomalous conditions

DATA PRODUCTS

- GDRs
  - Cycles 1-76 completed
  - Cycles 1-74 distributed by PODAAC (75-77 due 9 Dec.)
- IGDRs
  - Currently processing Cycle 81
  - Cycles 1-80 completed

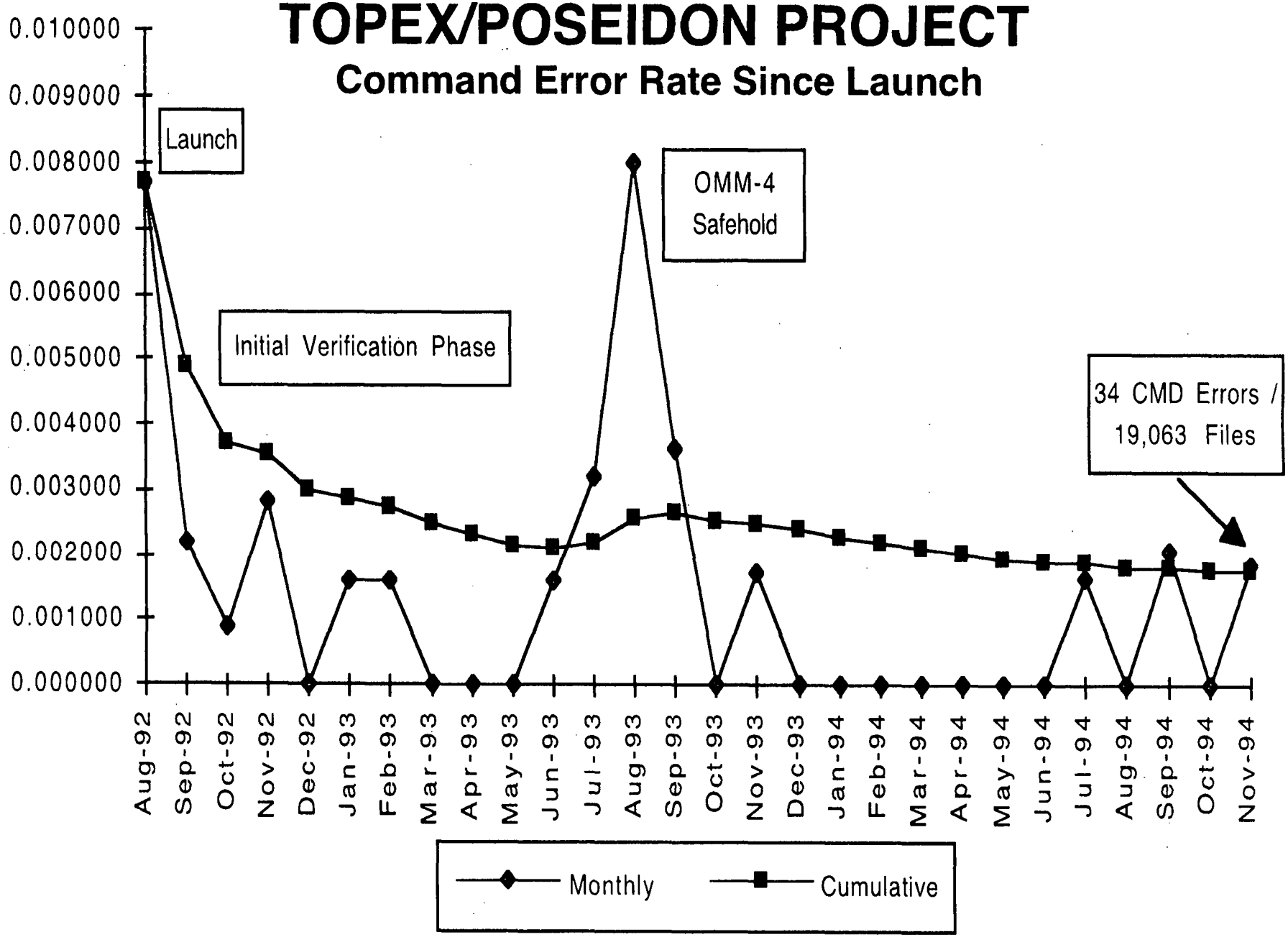
TOPEX Percent Processed of Available Time



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TOPEX/POSEIDON PROJECT

Command Error Rate Since Launch



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MEASUREMENT ACCURACIES

one sigma values in cm

	TOPEX	POSEIDON	REQUIREMENT
Altimeter			
Altimeter Noise	1.7	2.0	2.0
EM Bias	2.0	2.0	2.0
Skewness	1.2	1.2	1.0
Ionosphere	.5	1.7	2.2
Dry Troposphere	.7	.7	.7
Wet Troposphere	1.1	1.1	1.2
Total Altimeter Range	3.2	3.7	4.0
Precision Orbit			
Radial Orbit Height	3.5	3.5	12.8
Sea Surface Height			
Single-Pass	4.7	5.1	13.4

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

EXTENDED MISSION

- Prime Mission – through September 1995
- Extended Mission – Currently being planned until September 1998 (3 years)
  - Reduced funding levels
  - Operating Plans to be developed by mid-March '95

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

CNES PROJECT STATUS

- OVERVIEW
- DORIS / SSALT STATUS
- DATA PRODUCTS
- EXTENDED MISSION

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

OVERVIEW

- NOMINAL OPERATIONS
  - DORIS CONTINUOUS OPERATIONS
  - SSALT TURN-ONs : 1 CYCLE EVERY TEN CYCLES
  - SINGLE EVENT UPSETS BREAK ROUTINE
- DATA PRODUCTS DELIVERED ON SCHEDULE
- HIGH LEVEL OF EXPERTISE MAINTAINED TO PREPARE FUTURE MISSIONS
- IMPORTANT OUTREACH ACTIVITIES

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

DORIS

- CONTINUOUS OPERATIONS
- SOME SINGLE EVENTS UPSETS
  - –> NO DISCONTINUITY ON POD PRODUCT
- START of GROUND BEACONS REPLACEMENT
  - USE OF NEW GENERATION BEACONS (lower mass, lower power demand, lower cost)
- NETWORK DENSIFICATION UNDERWAY
  - about 10 new sites investigated
- NEW RECEIVER UNDER DEVELOPMENT FOR FUTURE MISSIONS
  - lower mass
  - Simultaneous tracking of 2 beacons
  - real time on-bord orbit determination included

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

SSALT

- NOMINAL OPERATIONS
- SEU SENSITIVITY
- CONTINUOUS EXPERTISE ACTIVITY
  - EXPERIMENTAL SENSOR
  - REQUIREMENTS MET
  - USE OF IN FLIGHT ACTUAL DATA
    - » ON BOARD SOFTWARE IMPROVEMENTS
      - NOISE LEVEL REDUCTION
      - APPARENT TRACKER BIAS UNDERSTANDING
  - VALIDATION and IMPROVEMENTS FOR FUTURE MISSIONS

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

DATA PRODUCTS

- CNES POEs, IGDRs, GDRs PRODUCED ON SCHEDULE
- MERGED GDRs PRODUCED and DISTRIBUTED ON SCHEDULE
- AUXILIARY PRODUCTS : eg TIDES MODEL CD-ROM

TOPEX/POSEIDON SCIENCE WORKING TEAM
4 December, 1994

EXTENDED MISSION

- CONTINUOUS OPERATIONS MADE ON A MULTIMISSION BASIS
  - DORIS/SPOT2 (1990 - ?)
  - TOPEX/POSEIDON (1992 - 1995 - 1998 - ?)
  - DORIS/SPOT3 (1993 - ?)
  - DORIS/SPOT4 (1997 - ?)
  - DORIS/ENVISAT, TPFO, ...
- HARWARE, SOFTWARE, TEAMS MAINTAINED BEYOND TOPEX/POSEIDON

SWT ISSUES

L.-L. FU

TOPEX/POSEIDON SWT MEETING

DECEMBER 4, 1994

TOPICS

- SCIENCE PUBLICATIONS
- COMMUNICATION AND COORDINATION
- EXTENDED MISSION SCIENCE PROGRAM

PUBLICATION OF SCIENCE RESULTS

- PUBLICATIONS IN SCIENCE, NATURE
  - TIDE MODEL (LE PROVOST, CARTWRIGHT, BENNETT; SUBMITTED)
  - GLOBAL MEAN SEA LEVEL (NEREM ET AL.)
  - SEASONAL CYCLES
  - COMPARISON WITH NUMERICAL MODELS
  - ENSO PREDICTION

PUBLICATION OF SCIENCE RESULTS (CONT'D)

- SECOND JGR SPECIAL ISSUE
  - CURRENT DEADLINE - FEB 1, 1995
  - EARLY PAPERS ALREADY SUBMITTED (TO BE INCLUDED IN A SPECIAL REPRINT VOLUME)
  - 18 TITLES RECEIVED FOR THE SECOND ISSUE
  - ANTICIPATE INCLUDING THE BULK OF THE PAPERS PRESENTED IN THE AGU SPECIAL SESSIONS
  - IS THE CURRENT DEADLINE VIABLE?

SCIENCE TEAM MEETINGS

- REACHING THE PRIME TIME OF THE MISSION
- THE QUALITY AND AMOUNT OF DATA SHOULD GENERATE SUFFICIENT INTERESTS FOR MORE FREQUENT SCIENCE MEETINGS
- ENHANCE COORDINATION AND EFFICIENCY IN PUBLICATIONS AND OUTREACH ACTIVITIES
- SEMIANNUAL MEETINGS ARE DESIRED
- PROPOSE A MID-YEAR SWT MEETING AT JPL (MAY 8, 1995)

COMMUNICATIONS

- T/P INTERNET BULLETIN BOARD
- MOSAIC HOME PAGES
- T/P RESEARCH NEWS

EXTENDED MISSION SCIENCE PROGRAM

- PERFORMANCE REVIEW OF EACH PI TEAM TO DETERMINE FUNDING LEVEL FOR THE EXTENDED MISSION

  PEER-REVIEWED PUBLICATIONS

  EFFECTIVENESS IN CARRYING OUT PROPOSED OBJECTIVES

  SCIENCE PLAN FOR EXTENDED MISSION INVESTIGATIONS (INCLUDING THE QUALITY OF THE TEAM COMPOSITION)

- TEAM RESTRUCTURING IS ENCOURAGED

Yves Menard

PLANS FOR THE 95 MEETING:

OPERATIONAL OCEANOGRAPHY AND SATELLITE OBSERVATION

Y. Menard

CONTEXT:

In the continuity of the 93 JASO symposium with extension to satellite systems other than altimetry, i.e. scatterometry, radiometry, radar...

Joint organization between CNES, SMF (Société Météorologique de France) and METEO-FRANCE.

Opportunity to demonstrate the major role of TOPEX/POSEIDON like missions in future permanent observation systems (GOOS is now recognized as a high priority by the international community).

SCIENTIFIC PROGRAM:

1. Oceanographic applications and space data requirements:

- Climatic watch
- marine meteorology
- ocean forecasting
- management of marine resources

2. Observation systems for operational oceanography

- satellite sytems (altimetry, scatterometry, radiometry...)
- Links between satellite and ground systems
- Access to data and products

3. Assimilation of data into models

- Assimilation techniques
- Verification of observations
- Applications

4. Socio-economic impact

SCIENTIFIC COMMITTEE

In the process of being formed
Participation of several T/P investigators will be requested

ORGANIZATION:

Tentative date: 16-20 of October 1995

First day will be devoted to the TOPEX/POSEIDON Science Working Team. The symposium will then proceed by half-day with one plenary session inclucing invited papers followed by the poster session (all contributed papers).

French-English translation will be provided excepted for the SWT

Place: Biarritz (a city bordering the Atlantic Ocean, in the south-west of France). The symposium will be held at the « Casino de Biarritz » just in front of the sea (gambling permitted at night)

CALL FOR PAPERS

1rst announcement to be sent end of December 1994
2 nd announcement May 1995
Abstract submission deadline: 15 June 1995
Acceptance by September 15
Papers sent in time will be edited in a special issue of « La Météorologie » journal

TOPEX/POSEIDON

OUTREACH PROGRAM

OVERVIEW

Edward J. Christensen

Science Working Team Meeting
SanFrancisco, California
December 4, 1994

WHAT IS OUTREACH?

o Outreach is the process by which an organization transfers knowledge about its products and services to outside organizations, communities, and constituents for the benefit of these entities. Done properly, the organization will in turn benefit from the support and the goodwill of the said entities.

o For TOPEX/Poseidon, we define outreach to have the following components:

> Public Information: To inform the public of exciting science, engineering, and community services derived from TOPEX/Poseidon.

> Educational Outreach: To inspire and interest students in their formative years (K - 6th grade) in science, enhance the science education of the Junior and High School students, and facilitate science and engineering educational opportunities for college students through the graduate level.

> Technology Commercialization: To facilitate transfer of the new technologies developed at the laboratory to the private sector .

TOPEX/POSEIDON's OUTREACH OBJECTIVE

Within the context of Global Change and Earth Remote Sensing from space, use the engineering and science of TOPEX/Poseidon to enhance science education of K-12th grade students, college students, university students, members of industry, and the general public.

THE TOPEX/POSEIDON OUTREACH PROGRAM CORE TEAM

o Project External:

> Classroom Teachers (2)
> University Professors (2)
> Educational Specialist
> Curriculum Developer
> Department-of-Education Representative

o Project Internal:

> Project Scientist
> Project Manager
> Outreach Manager
> The Science Working Team
> Computer Multimedia Expert
> Video-and-Print Expert
> Educational Affairs Office Representative
> Public Information Office Representative

TOPEX/POSEIDON OUTREACH PROGRAM CORNERSTONES

- o Computer Multimedia Products
  - > TOPEX/Poseidon Internet Node (Mosaic Home-Page)
  - > CD-ROMs of Educational Material
- o Video Products
  - > TOPEX/Poseidon Mission Description and Science Results
  - > Videos of Educational Material
- o Curriculum Development and Involvement
  - > Educational Packages
  - > Teacher Workshops
  - > Classroom Lectures
  - > Public Lectures
- o News Media
  - > Newspaper Articles
  - > Television News and Features (Weather, NOVA, DISCOVERY)

THE TOPEX/POSEIDON MOSAIC HOME_PAGE
<http://topex-www.jpl.nasa.gov>

Near-Term Capabilities

- o A Complete Browse-and-Select Atlas of Science Products
- o Animated Sequences of Global Science Parameters
- o A "Build-Your-Own" Animation Capability
- o An "El Nino Watch" Weather Service
- o Links to Home-Pages on Related Subjects
- o Tutorials on the Spacecraft, Instruments, and Related Science
- o Draft Publications and Abstracts of Technical Papers
- o A Mission Description, Including Orbit Animation
- o Biographical Sketches & Pictures of Program Scientists and Engineers
- o A Set of Research Newsletters
- o A Frequently Asked Questions List
- o A Calendar of Significant Events
- o Cross-Linking with TOPEX/Poseidon Specific and Related Subject Home-Pages

THE TOPEX/POSEIDON MOSAIC HOME_PAGE (contiued)
<http://topex-www.jpl.nasa.gov>

Future Capabilities

- o Videos through Mosaic
- o Lectures through Mosaic

The system is designed to interact synergistically with other related inter-disciplinary outreach Programs.

WHAT CAN THE SWT DO FOR OUTREACH RIGHT NOW?

- o Develop Mosaic Home-Pages
  - > TOPEX/Poseidon Specific
  - > Related Subjects (Oceanography, Climate, Global Change, etc.)
- o Provide URLs for Crosslinking With the TOPEX/Poseidon Home-Page
  - > Describe as 'Specific' or 'Related'
  - > Send URLs to <ejc@stealth.jpl.nasa.gov>
- o Make Presentations and Encourage Sudents and Staff to Make Presentations To:
  - > Public Schools and Universities
  - > Public Societies, Clubs, etc.
- o Contribute to Computer Multimedia, Video, and Curriculum Product Development
- o Report Significant Scientific Results to the News Media

OUTREACH OF TOPEX/POSEIDON MISSION

by P. Vincent (CNES),
Y. Menard (CNES),
F. Blanc (CLS),
and P. Y. Le Traon (CLS)

TP SWT Dec. 94

UNTIL NOW

- UNTIL NOW: PROMOTION ESSENTIALLY THROUGH SEMINARS, MEETINGS, NEWSLETTERS, SUMMER SCHOOLS

- SUMMER SCHOOLS
  - PUBLIC: PROFESSORS, TEACHERS, ETC.
  - BREST, JULY 1994
  - CAYENNE, JULY 1995

P. Vincent, TP SWT Dec. 94

A NEW AVISO FUNCTION: AN INFORMATION SERVER PROTOTYPE

- PRESENT TARGET:
  - RESEARCH COMMUNITY OF ALTIMETRIC USERS
  - GENERAL SCIENCE COMMUNITY
- WORKING SINCE DEC. 1ST, 1994
- ACCESS: http://192.134.216.41

P. Vincent, TP SWT Dec. 94

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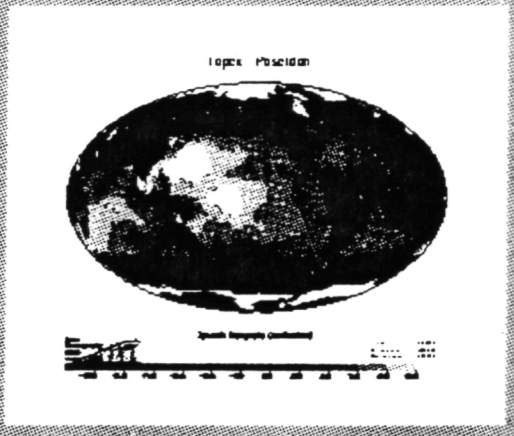
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aviso ALTIMETRIE

cnes

Space Oceanography Group CLS

AVISO / TOPEX-POSEIDON Information System



Documentation is available on the following topics :

- The TOPEX/POSEIDON mission
- The AVISO/altimetry mission
- Information on last TOPEX/POSEIDON processed cycle
- Outline of TOPEX/POSEIDON results
- Bibliography
- Glossary

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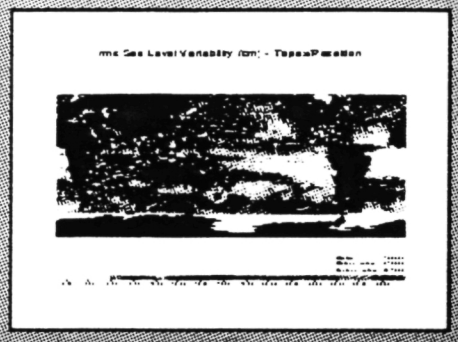
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Document Title: TOPEX/POSEIDON Scientific Results

Document URL: http://132.149.34.50/curt/tpe/SRes.html#See

Rms of sea level variability



The global rms variability of sea level as determined from the first two years of TOPEX/POSEIDON data mainly shows the regions of high ocean variability associated with strong ocean currents (Gulf Stream, Kuroshio, Brazil/Malvinas Confluence area, Antarctic Circumpolar current, Agulhas current). These signals have typical amplitudes of 30 cm (rms). They correspond to eddies and rings with typical scales of a few hundred km. In areas with low ocean variability (most of the oceans), the sea level variability observed by TOPEX/POSEIDON is typically only 4-5 cm rms.

Large scale sea level variations



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REVISION 1 OF THE PROTOTYPE

- JANUARY 1995
- NEW SCIENCE RESULTS: RELATED TO THE ALTIMETER TECHNIQUE ITSELF, TO OCEANOGRAPHY AND GEOPHYSICS
  - OPEN TO ANY SCIENCE PROVIDER (INTERNAL AND EXTERNAL TO THE AVISO ENVIRONMENT)
- NEW ITEMS FOR NEW TARGETS:
  - PRESENTATION OF ALTIMETRY FOR EDUCATION ENTITIES
  - TEXTS AND GRAPHS ISSUED FOR SUMMER SCHOOLS
  - PRESENTATION OF MAJOR THEMATIC SCIENCE RESULTS ISSUED FROM T/P ALTIMETRY

P. Vincent, TP SWT Dec. 94

PERIODIC REVISIONS OF PROTOTYPE

- **ESSENTIALLY TO REGULARLY UPDATE:**
  - **THE AVISO INFORMATION ON THE LAST PROCESSED T/P CYCLE**
  - **THE T/P <u>SCIENCE RESULTS FROM ANY PROVIDER</u>**

(Short notice to be sent to all PI's : "How to prepare your information/results package for inclusion in the AVISO server").

P. Vincent, TP SWT Dec. 94

OPERATIONAL VERSION OF THE AVISO SERVER

- ALL MISSIONS of the PROTOTYPE
- NEW FEATURES:
  - FORUM (MAILING)
  - ACCESS TO THE AVISO CATALOGUE OF PRODUCTS (see NEXT TALK ABOUT AVISO STATUS)
  - FTP ACCESS TO SELECTED PRODUCTS
- TARGET DATE for IMPLEMENTATION of NEW FEATURES: JUNE 1995

P. Vincent, TP SWT Dec. 94

TOPEX/POSEIDON OCEAN TIDES WORKSHOP SUMMARY

- 11 presentations for revised models and new models
- 5 presentations comparing Ocean tide models
  - Pelagic tide gauge / crossovers / acoustic tomography
- Objective:

  To recommend the TOPEX/POSEIDON Ocean tide model(s) based on results of the workshop

- Results: (~ 4 cm tidal improvement)
  - Significant advances in tidal modeling Science within the last year, with anticipated improvement in the near-future.
  - Difficult to recommend One single model

TOPEX/POSEIDON OCEAN TIDES MEETING

Second Session: Model Comparisons – C. Le Provost

- Intercomparison of recent ocean tide models: O.B. Andersen, P.L. Woodworth and R.A. Flather
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CSR
CENTER FOR SPACE RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

TOPEX/POSEIDON OCEAN TIDES MEETING

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- Global ocean tides from TOPEX, ERS-1 and GEOSAT altimetry: O.B. Andersen
- FES94.2: A global hydrodynamic solution for tidal elevations and currents: F. Lyard and C. Le Provost
- An Ocean tide model derived at the University of Colorado from TOPEX/POSEIDON altimetry and comparisons to some other models: S.D. Desai and J.M. Wahr
- Ocean tide model from 2 years of T/P altimetry: R. Eanes and S. Bettadpur
- Tidal analysis of TOPEX/POSEIDON altimetry: E.J.O. Schrama
- Tidal models based on TOPEX/POSEIDON altimeter data and a Proudman function basis: B.V. Sanchez and N.K. Pavlis
- Progress report on a generalized response method applied to TOPEX/POSEIDON: R.D. Ray, B. Sanchez and D.E. Cartwright
- TPXO.2: An eight constituent inverse solution for global ocean tides: G. Egbert, A. Bennett and M.Foreman

CSR
CENTER FOR SPACE RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

	Year	Hydrodynamic assumption	Contributes to data		Number of constituents	Area (Latitude)	Resolution	Remarks
			Altimetry	Tide Gauges				
Schwiderski	1980	Linear	No	Yes	11+5[4]	Global	1° x 1°	-
Cartwright & Ray	1990	None	GEOSAT	No	60[5]	+/- 69°	1° x 1.5°	Orthotides
Grenoble[1]	1994	Non-linear	No	No[2]	13[4]	Global	0.5° x 0.5°	Finite Elements
Mazzega[1]	1994	None	T/P	No	?	?	?	Inversion
OSU[1]	1994	Linear	T/P	No[3]	8+9[4]	-80°,70°	0.58° x 0.70°	Global Inversion
Ray, et al.[1]	1994	None	T/P	No	60[5]	+/- 65°	1° x 1°	Orthotides, Proudman Functions
Sanchez & Pavlis[1]	1994	None	T/P	No	8	-77°,69°	2° x 2°	Proudman Functions
Schrama & Ray[1]	1994	None	T/P	No	4	+/- 65°	1° x 1°	Harmonic Analysis
Texas[1]	1994	None	T/P	No	60[5]	+/- 66°	1° x 1°	Orthotides
Andersen	1994	None	T/P,ERS-1	No	60[5]	-80°,80°	0.75° x 0.75°	Orthotides
Andersen, (T/P adj. Grenoble)	1994	'Non-linear'	T/P	No	13	Global	0.5° x 0.5°	Orthotides, FE
Ohio (Rapp)	1994	None	T/P	No	4	+/- 65°	1° x 1.5°	Spherical Harmonics
Knudsen	1994	None	T/P	No	4	+/- 65°	1° x 1.5°	Spherical Harmonics

[1] Model is available on the CD-ROM,
[2] The Grenoble model does not use tide gauges through the whole domain, only at the interfaces of sub-domain areas,
[3] The OSU model does not use tide gauge data in the present form but is prepared to use this type of information,
[4] Additional constituents have been induced by admittance,
[5] Number of constituents included in the tide generating potential for the orthotide formulation.

- New models (not widely available)

- Later versions available than cdrom.

Others

- Texas - Ma et al. (Not pub. available)
- Colorado - Wahr / Desai (2 months)
- NOAA - Wagner/Tai
- Kantha - Data-assimilating model
- Grenoble assimilated hydro. model (LeProvost et al) - FES94.2
- Andersen - T/P adjusted Grenoble model
- Knudsen model

New models (not widely available)

TIDE MODEL RECOMMENDATION

- Project wants recommendation of a single model

- Six models selected based on criteria : (1) models include at least 8 major tidal lines and/or use ortho tides
  (2) models "widely" available for at least 2 months & before this meeting

- All models perform similarly in deep Ocean, all have some problems – no model stands out as the best

- Recommendation of model(s) now likely will face with the prospect that the "best" models will appear in the near-future

ACCURACY EVALUATIONS OF RECENT OCEAN TIDE MODELS

Selected Ocean Tide Models:

- CSR 2.0 - UT/CSR Version 2.0 model
- OSU - Oregon State Univ. TPXO.2 model
- Gren - Grenoble hydrodynamical model
- RSC - Ray, Sanchez & Cartwright model
- GSFC94A - Pavlis & Sanchez model
- Desai - Desai & Wahr model
- CSR T/G - UT/CSR T/P+Geosat model

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ACCURACY EVALUATIONS OF RECENT OCEAN TIDE MODELS

Evaluation Criteria (in order of importance):

1. Model must include at least 8 major tidal lines and/or use orthotides representation
2. Pass deep ocean (>800 m) tide gauge test
3. Pass deep ocean altimeter crossover residual (T/P, ERS-1, and Geosat) test
4. Corrected T/P data with the model should show "real" oceanography
5. Pass shallow ocean (≤800 m) crossover residual test
6. Model should be defined globally, includes coastal, shallow and large inland seas
7. Pass shallow ocean tide gauge test

ALTIMETER CROSSOVER EVALUATIONS OF SELECTED OCEAN TIDE MODELS

	Deep Ocean			Shallow Ocean		
	T/P (cm)	ERS-1 (cm)	Geosat (cm)	T/P (cm)	ERS-1 (cm)	Geosat (cm)
CSR 2.0	6.6	9.9	10.3	11.4	14.7	13.6
CSR T/G	6.6	9.8	10.2	12.0	13.6	13.3
Desai	6.7	10.1	10.4	11.4	15.6	13.7
RSC	6.9	9.7	10.5	10.7	12.9	13.3
OSU	7.5	10.0	10.5	11.8	13.9	14.3
GSFC94A	7.8	10.3	11.0	12.0	13.9	13.5
Grenoble	8.2	10.2	11.0	11.1	13.6	13.0

- Deep ocean (> 800 m depth), shallow ocean (≤ 800 depth)
- No. of cx. : 52,968 T/P, 16,981 ERS-1, 24,257 Geosat

Models ranked according to the lowest deep ocean T/P crossover residuals

RMS Differences Between Tide Models and Tide Gauge Data(cm)

Global Ocean

Model	M2	S2	K1	O1	RSS	Count
CSR2.0	1.56	1.09	1.05	0.84	2.33	86
DESAI	1.55	1.02	0.99	0.84	2.26	86
GSFC94A	1.67	1.16	0.97	0.80	2.39	86
OSU	1.68	0.98	1.08	0.80	2.37	86
RSC	1.58	1.18	1.04	0.85	2.39	86
~~KANTHA~~	~~1.96~~	~~1.47~~	~~1.42~~	~~0.92~~	~~2.98~~	~~86~~
CORRCR	1.96	1.84	1.65	1.02	3.32	86
CR1991	2.99	2.14	1.73	1.07	4.20	86
SCHWID	3.81	1.59	1.35	1.03	4.47	86

Accuracy improvement:

4.5 cm → 2.3 cm

~ 4 cm tidal improvement

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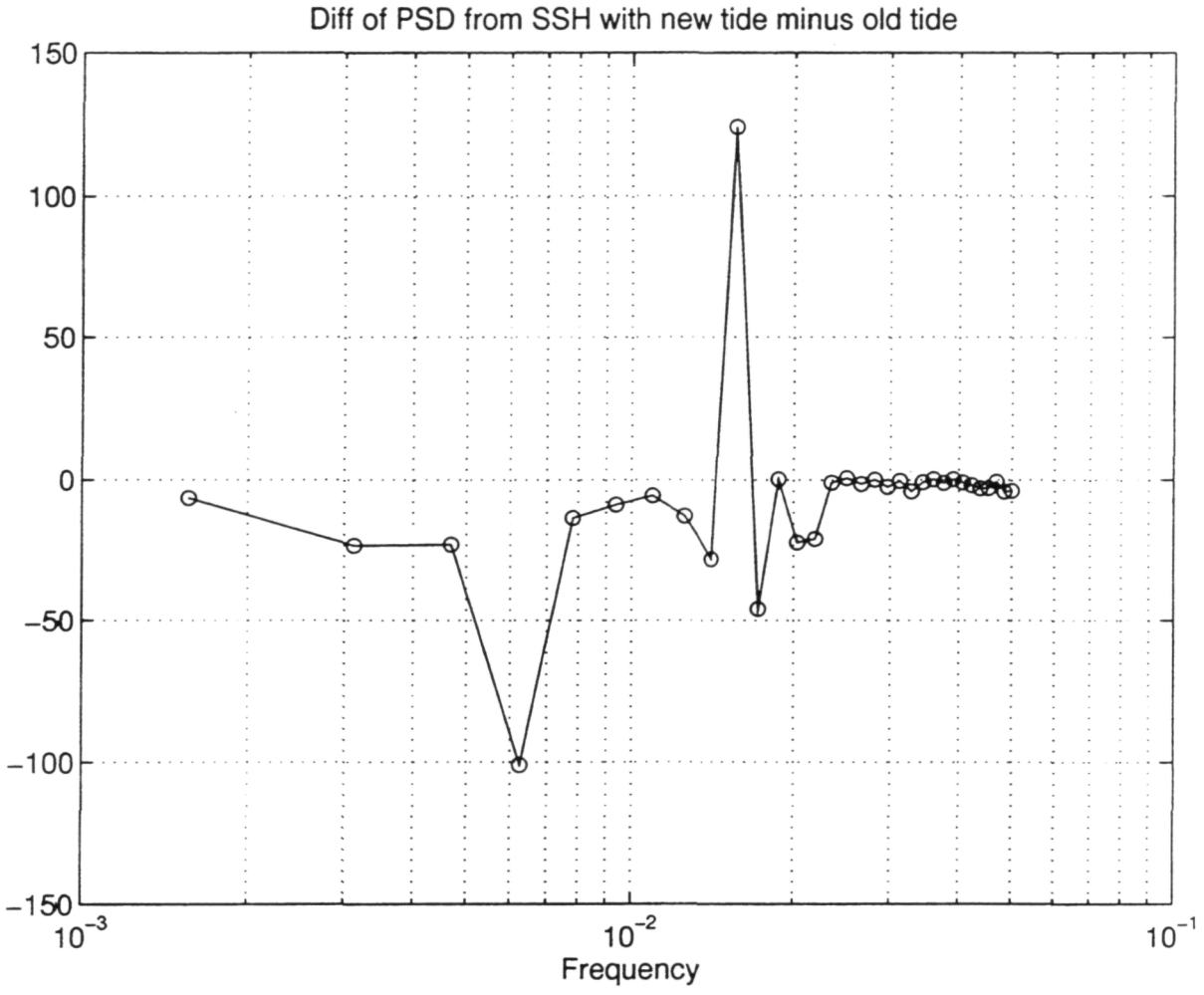
Issues / Model Uniqueness

- Global Coverage (high latitude; above/below ± 66°; inland seas)
  - Grenoble model
- Radiational tide correction implementation
  - RSC model
  - Desai/Wahr model
- FCN correction
  - Desai/Wahr model
- Improved Orbits (JGM-3 gravity model & TOPEX tide model)
  - CSR 2.0 model
- Better documentations (including bench mark tests)

for the models strongly requested

CSR 2.0
- Patched w/ Schw. above ± 66°

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Diff of PSD from SSH with new tide minus old tide
150
100
50
0
−50
−100
−150
10^{-3}
10^{-2}
10^{-1}
Frequency

D. stammer

RECOMMENDATIONS

- Shallow ocean, ~~and~~ extreme latitudes, inland usage (i.e. Hudson Bay, Med. sea)
  - Grenoble FES94.2 0.5 x 0.5 model
- Deep Ocean model(s):
  - CSR 2.0
  - Desai/Wahr
  - GSFC94A
  - OSU
  - RSC
- To be recommended in the next month or so
- ~~Welcome~~ Solicit opinions via email to help decision

STATUS REPORT OF THE FRENCH POD PRODUCTION GROUP :

SERVICE D'ORBITOGRAPHIE DORIS (SOD)

F. Nouel

- PRODUCTION REPORT
- ANTICIPATED UPGRADES
- POD INVESTIGATIONS
- ANTICIPATED ORBIT PRODUCTS

CNES MATHEMATIQUES SPATIALES
METROLOGIE DE L'ORBITE



SERVICE D'ORBITOGRAPHIE DORIS : PRODUCTION REPORT FOR T/P

- DORIS DATA COVERAGE : 77 % TO 83 % DORIS BEACON AVAILABILITY

  EVENTS OVER A FEW DAYS : CYCLES 10, 11, 24, 33, 37, 68

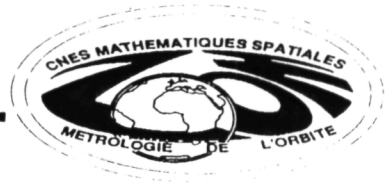
- CNES PRECISE ORBIT EPHEMERIS : 100 % LASER + DORIS

  RMS CNES POE / NASA POE ~ 2.5 CM ON RADIAL COMPONENT

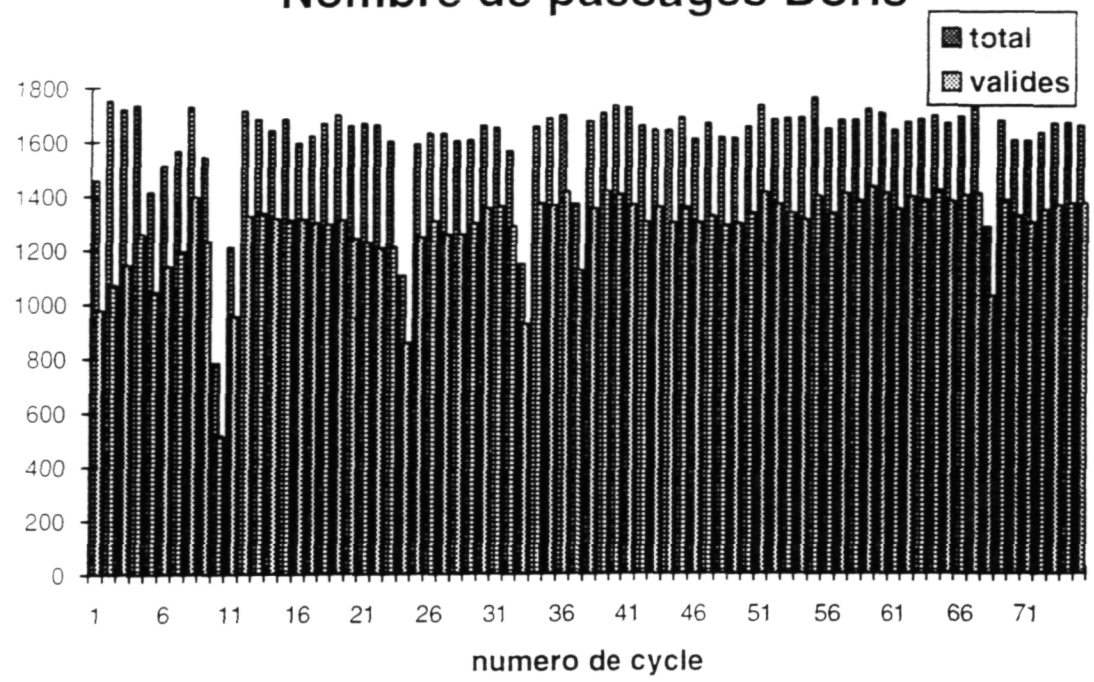
- DORIS DATA DELIVERY ~ 99 % ON TIME

  1 % WITH ONE OR TWO DAYS DELAY

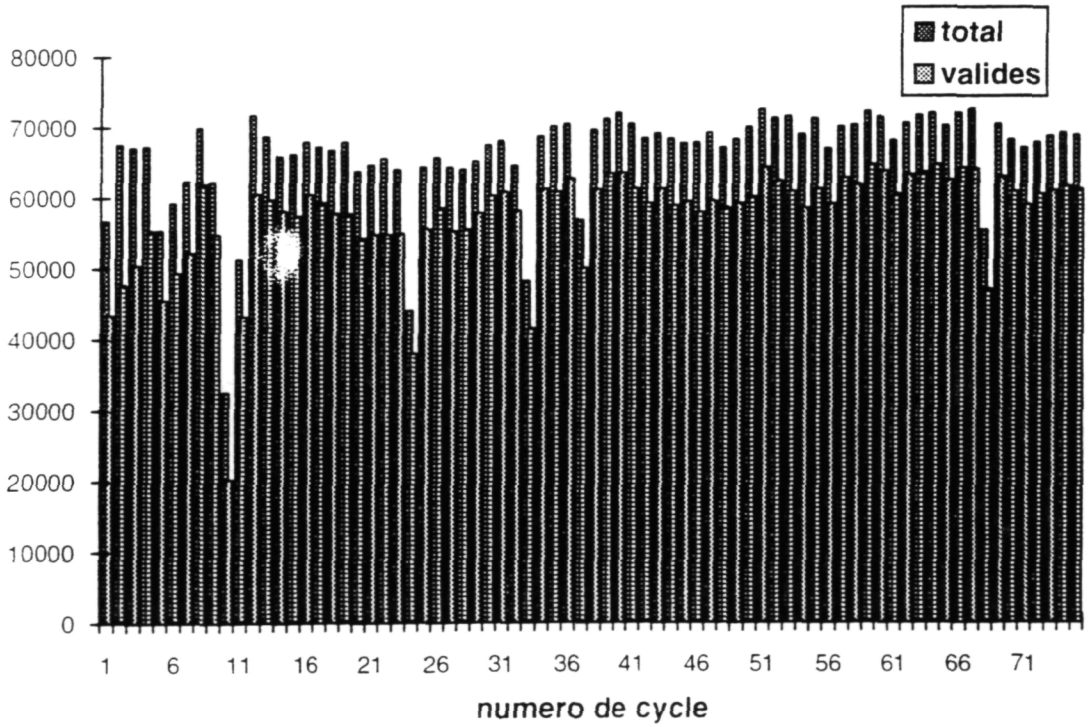
- SAME SERVICES ON SPOT2 AND SPOT3



Nombre de passages Doris



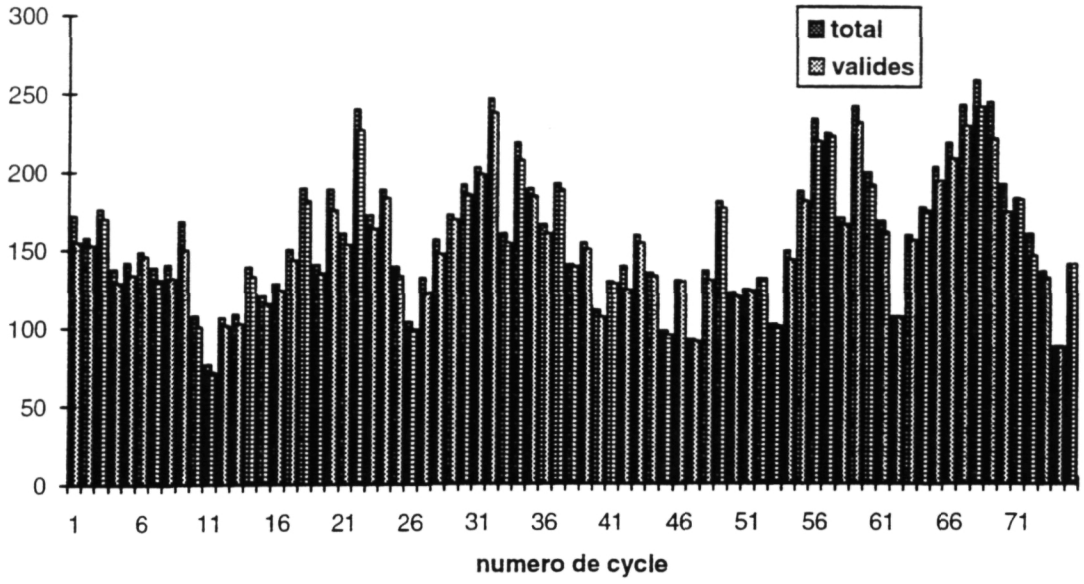
Nombre de mesures DORIS



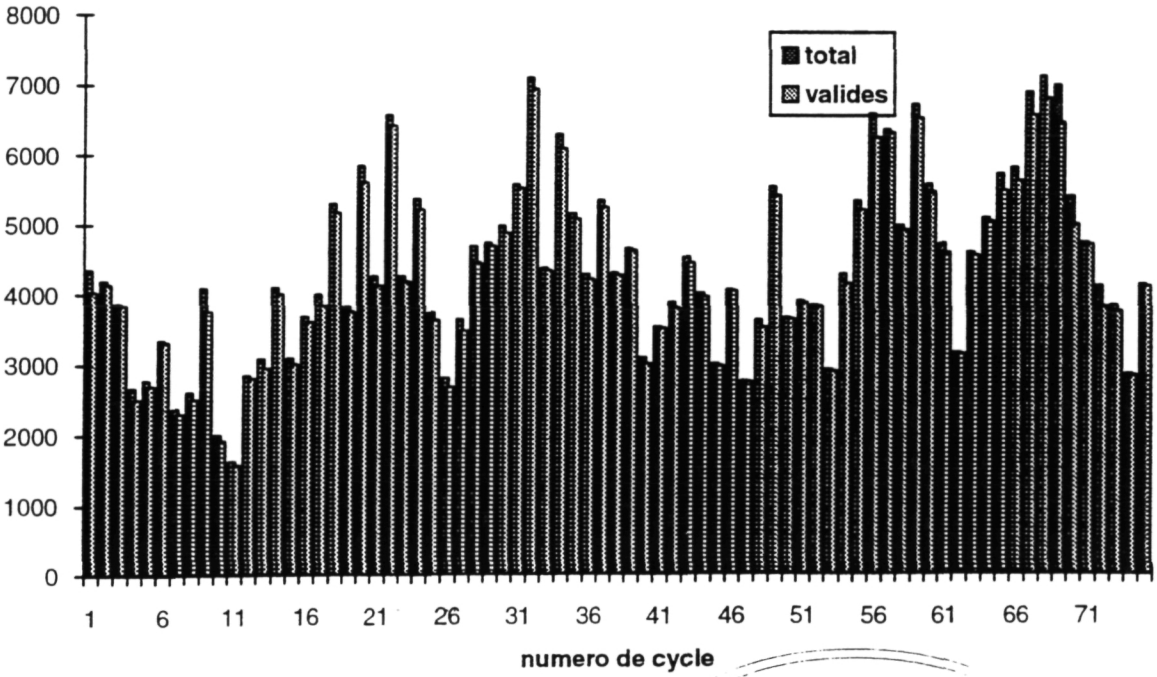
F. NOUEL - T/P SWT - AGU 1994 FALL MEETING

CNES MATHEMATIQUES SPATIALES
METROLOGIE DE L'ORBITE

Nombre de passages Laser

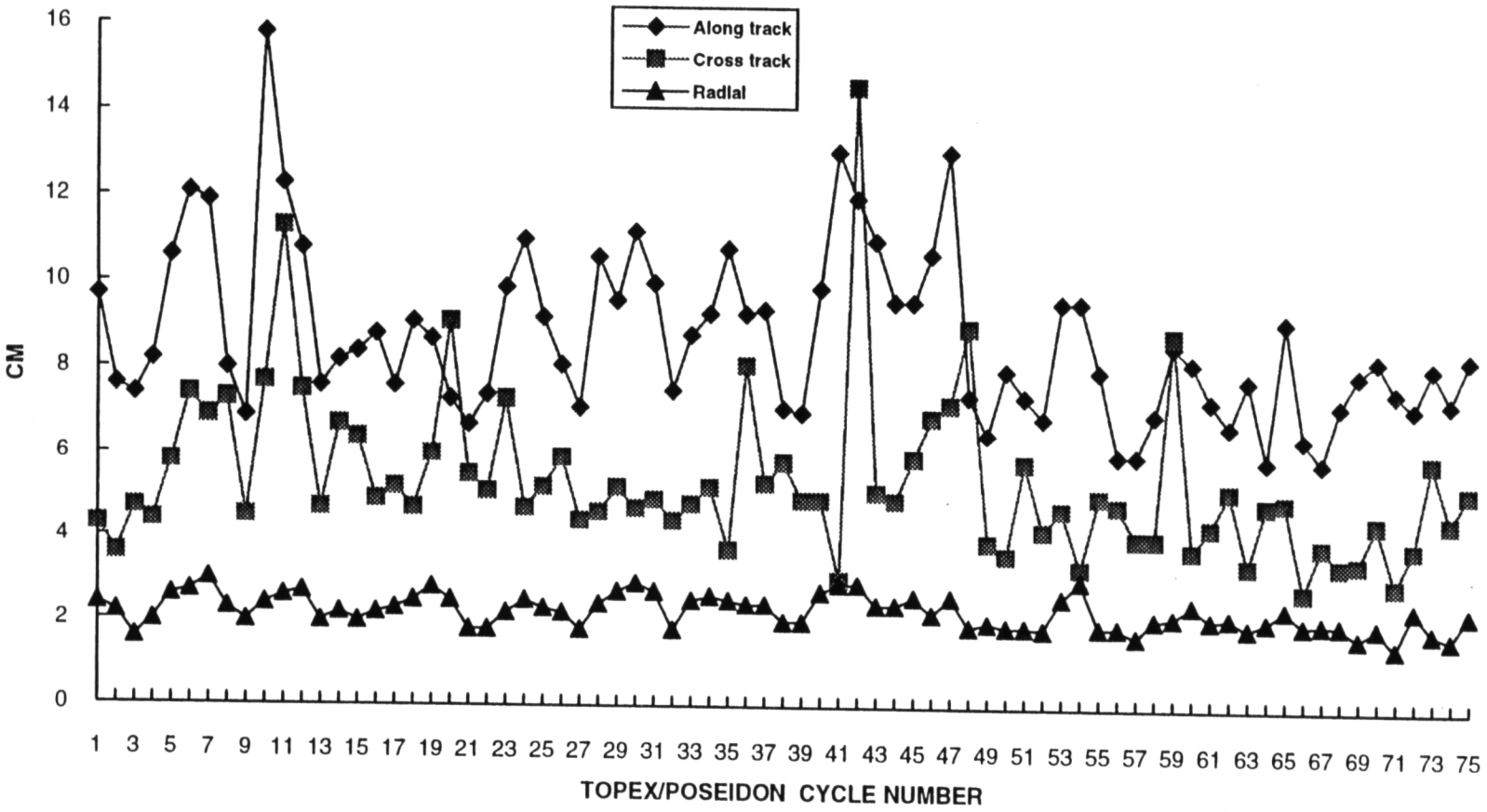


Nombre de mesures Laser



F. NOUEL - T/P SWT - AGU 1994 FALL MEETING

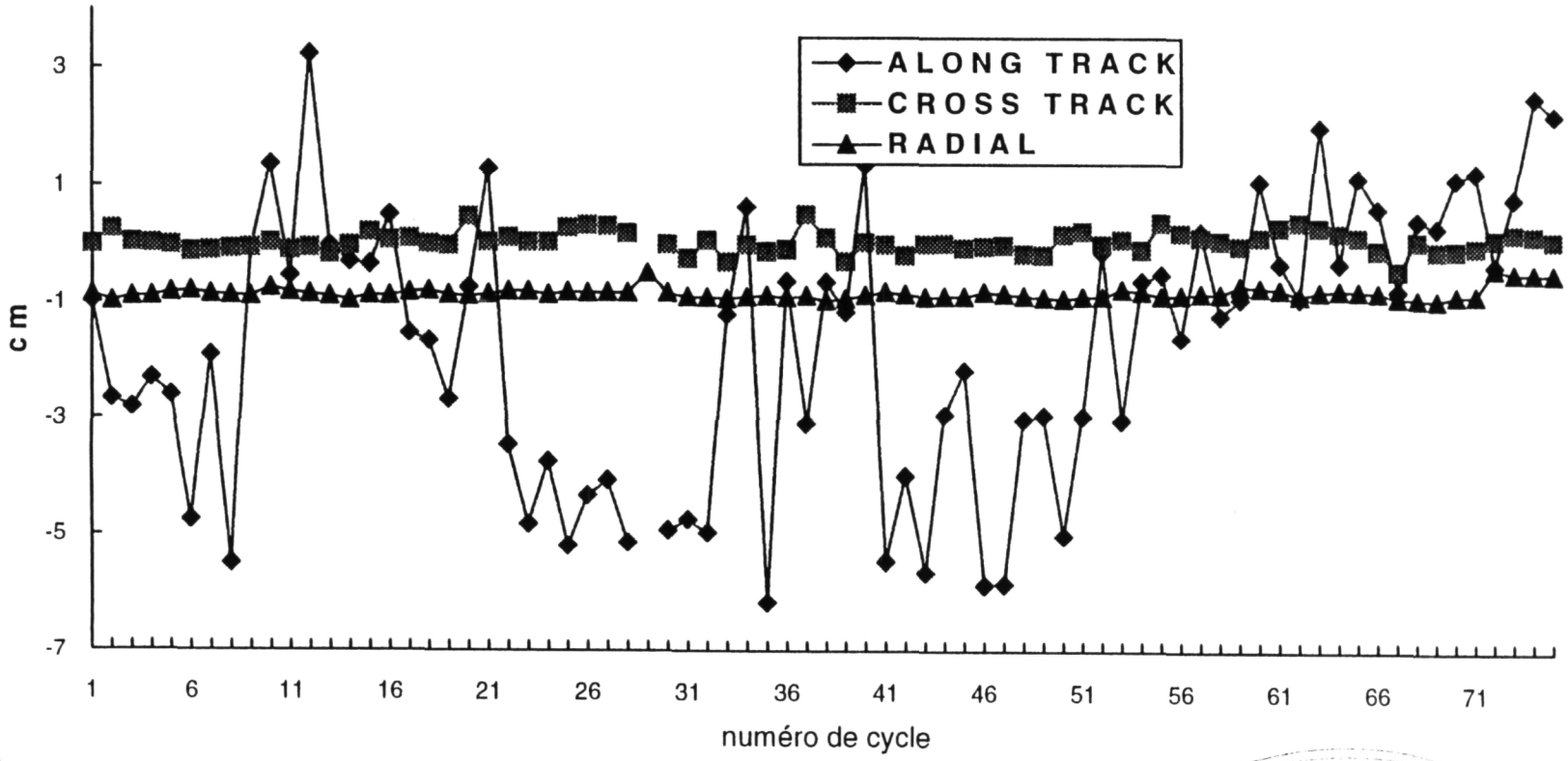
ORBIT DIFFERENCES RMS CNESPOE NASAPOE



F. NOUEL - T/P SWT - AGU 1994 FALL MEETING

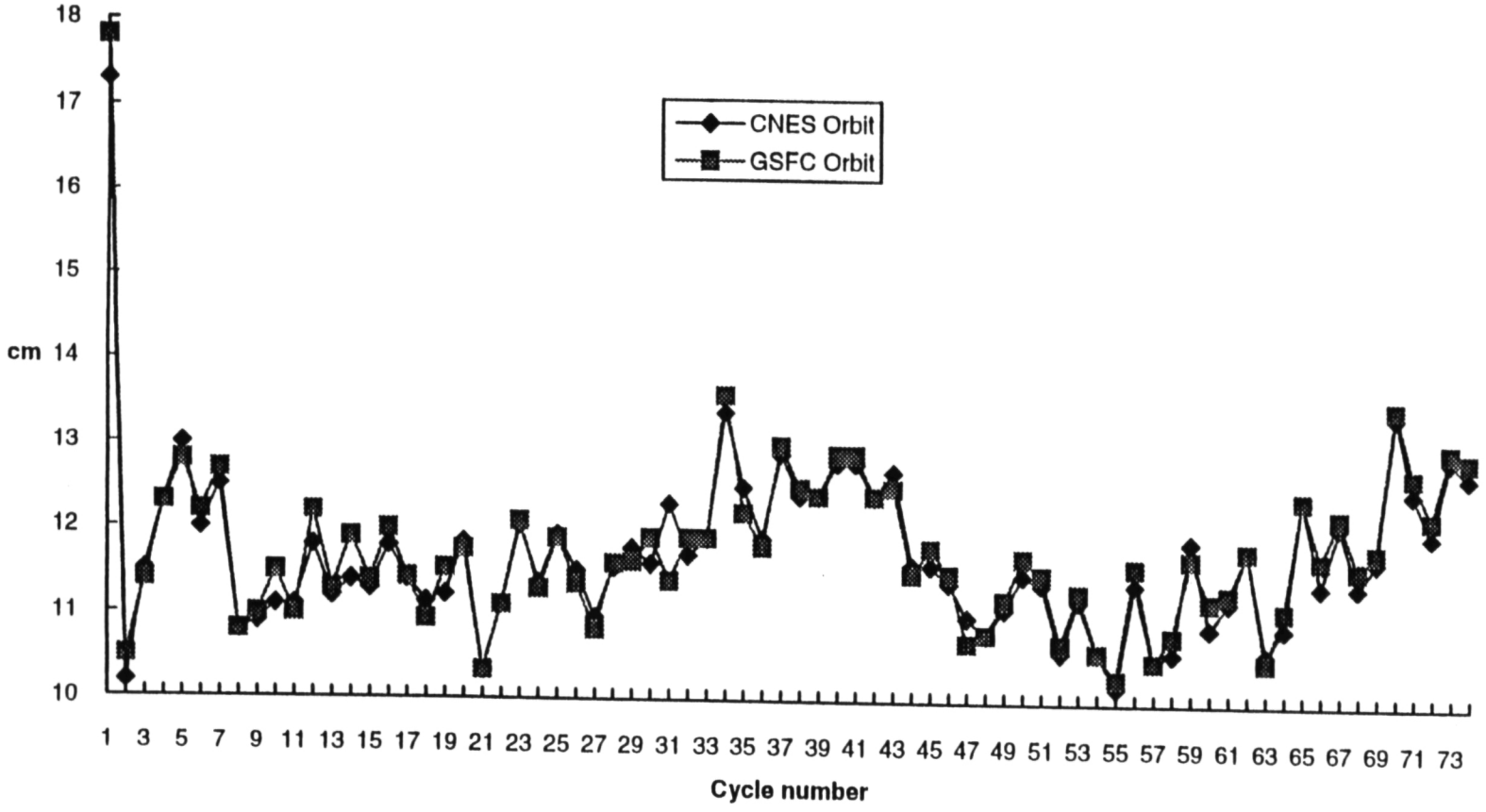
CNES MATHEMATIQUES SPATIALES
METROLOGIE DE L'ORBITE

Moyennes de la comparaison des orbites ZOOM/Mixte et GEODYN/Mixte



F. NOUEL - T/P SWT - AGU 1994 FALL MEETING

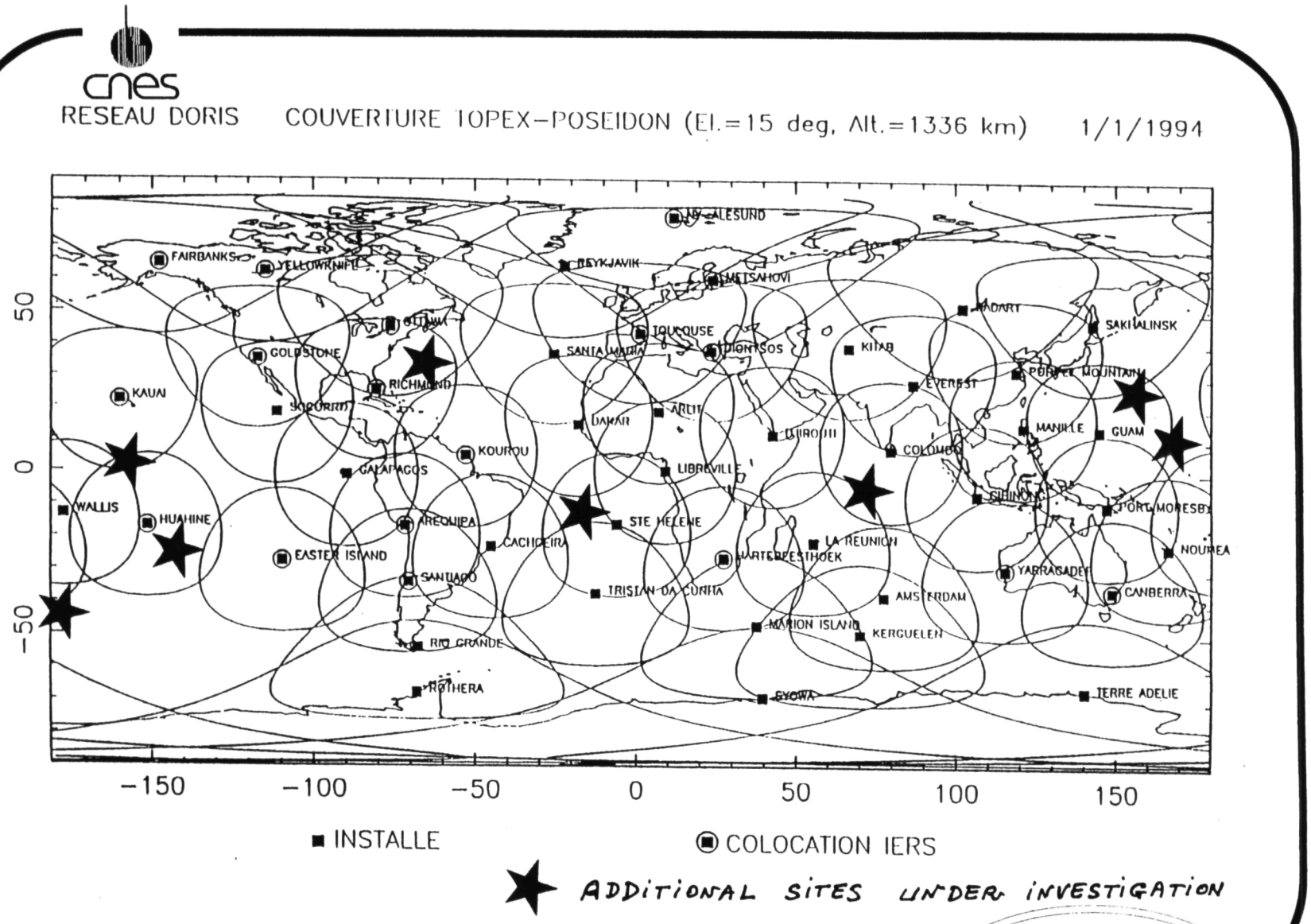
CROSSOVERS RESIDUALS RMS



F. NOUEL - T/P SWT - AGU 1994 FALL MEETING

ANTICIPATED UPGRADES

- **DORIS SYSTEM**
  - NEW BEACON (2.0 VERSION)
  - NETWORK REPLACEMENT $\sim$7 BEACONS PER YEAR
  - NETWORK EXTENSION $\sim$ 10 BEACONS
  - ON BORD RECEIVER 2 CHANNELS
  - IMPROVED OUS (1996)
- **ZOOM SOFTWARE**
  - GSFC OCEANIC TIDE MODEL (WORK CLOSE TO END)
  - RELATIVISTIC ACCELERATIONS
  - LASER MEASUREMENT EDITING
  - ZOOM CAN HANDLE DORIS DATA DELIVERED TO USERS ! (SHAME)
  - ZOOM 2000 : SUN/CRAY UNIX SYSTEM IN 96



F. NOUEL - T/P SWT - AGU 1994 FALL MEETING

POD/SOD INVESTIGATIONS

- DORIS IS CANDIDATE TO INTERNATIONAL EARTH ROTATION SERVICE (IERS)

  GEOCENTRIC REFERENCE FRAME
  EARTH ROTATION PARAMETERS
  STATION COORDINATES
  } => AFFECT LONG PERIODIC TERMS

- SOLAR ACTIVITY PARAMETERS

  MEAN FLUX $F_{10.7}$ MID TERM PREDICTIONS
  DORIS COVERAGE
  } CAN WE DEAL WITH THESE INFORMATIONS ONLY

OBJECTIVE : SHORTEN DELAYS - AFFECT LONG PERIODIC TERMS

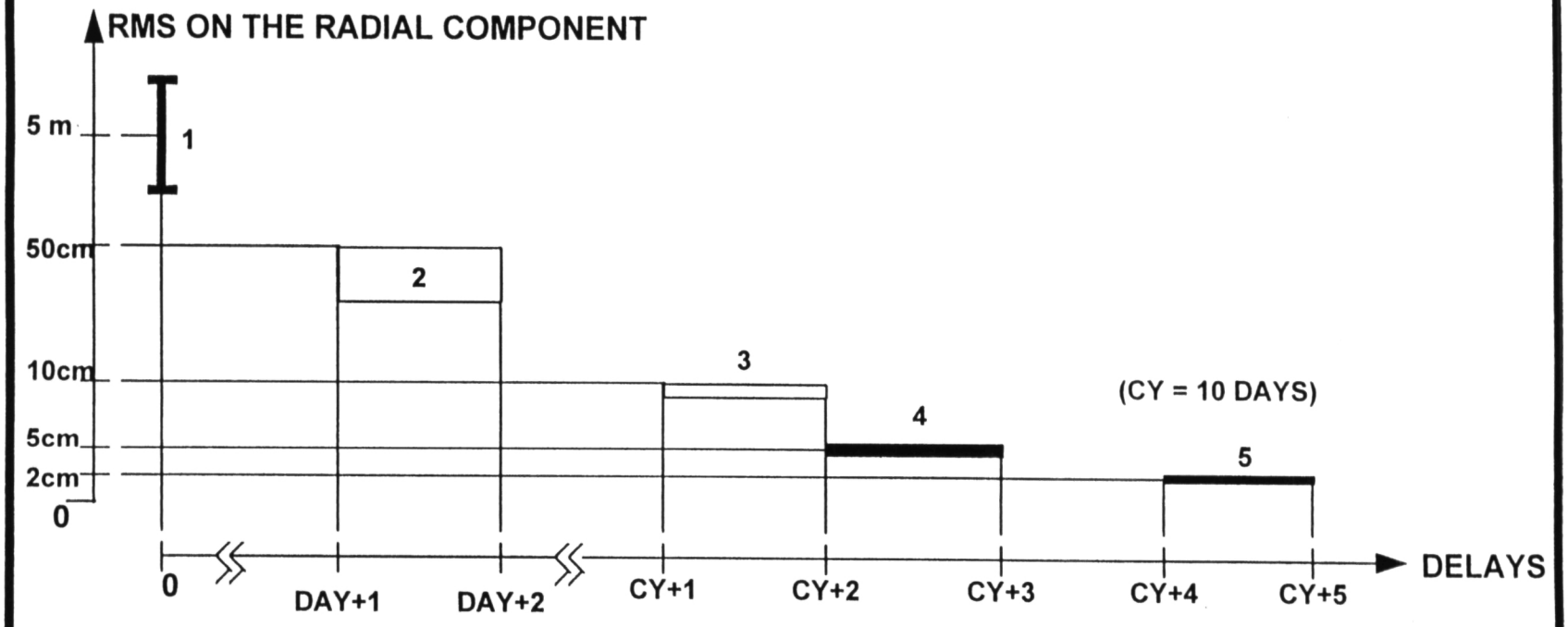
- REDUCED DYNAMIC WITH DORIS (WE PREFER STOCHASTIC FORCE MODELING)
  UNDER EVALUATION ON T/P CYCLES (BUT DIFFICULT !)

EX : * DORIS ONLY ORBITS + REDUCED DYNAMIC => { LASER RMS + CROSSOVERS RMS } DECREASE

* GENERAL RELATIVISTIC FORCES + REDUCED DYNAMIC : CROSSOVERS RMS INCREASE !

OBJECTIVE : GEOGRAPHICALLY CORRELATED ERRORS

ANTICIPATED ORBIT PRODUCTS (PREDICTIONS FOR TPFO ORBIT)



1 - REAL TIME, AVAILABLE ON BOARD : DORIS + DIODE

2 AND 3 - IMPROVEMENTS OF THE OPERATING SYSTEMS
- 2 DORIS CTDP
- 3 SOD (+ LASER)

4 - BASED ON ERP AND SOLAR ACTIVITY PREDICTIONS

5 - FAISABILITY TO BE PROVED

F. NOUEL - T/P SWT - AGU 1994 FALL MEETING

CONCLUSION

THE 2 CM CHALLENGE BRING US BACK

TO THE EARLY 10 CM TOPEX/POSEIDON CHALLENGE

NEW ORBITS AND ACCURACIES

TOPEX/Poseidon Precision Orbit Determination Team

Presented at the
TOPEX/Poseidon Science Working Team Meeting
San Francisco, California
December 4, 1994

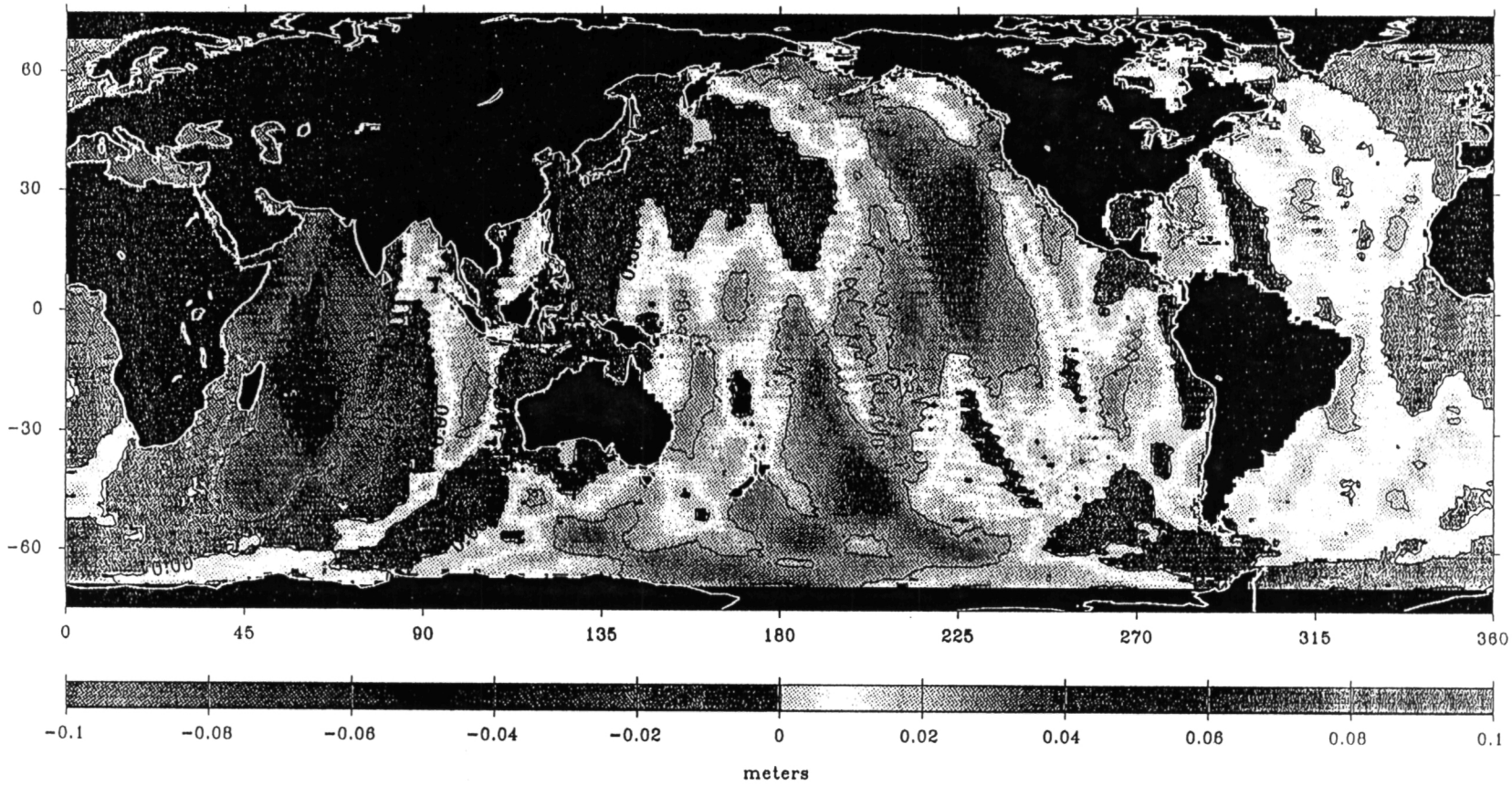
ORBIT DETERMINATION IMPROVEMENTS

- POD improvements investigated as part of verification task
- JGM-3 gravity model incorporates GPS tracking data
  - *Contribution of static gravity model errors reduced to ~1 cm*
- Ocean tide model based on T/P altimeter data
  - *Contribution of ocean tide model errors reduced to sub-cm level*
- Refinements in bias accelerations and estimation of additional empirical accelerations helps to reduce contributions of surface force model errors
  - *8-hr alongtrack accelerations decreases alongtrack orbit errors and improves fits, but no significant effect on radial orbit error*
  - *8-hr 1/revs provide insignificant improvement for radial component*
- Increase relative weighting of SLR data in orbit determination process
  - *Re-edit of SLR data and removal of known or observed biases*
  - *Orbit fits rival Lageos fits, so weighting closer to Lageos adopted*

THE JGM-3 GRAVITY FIELD MODEL

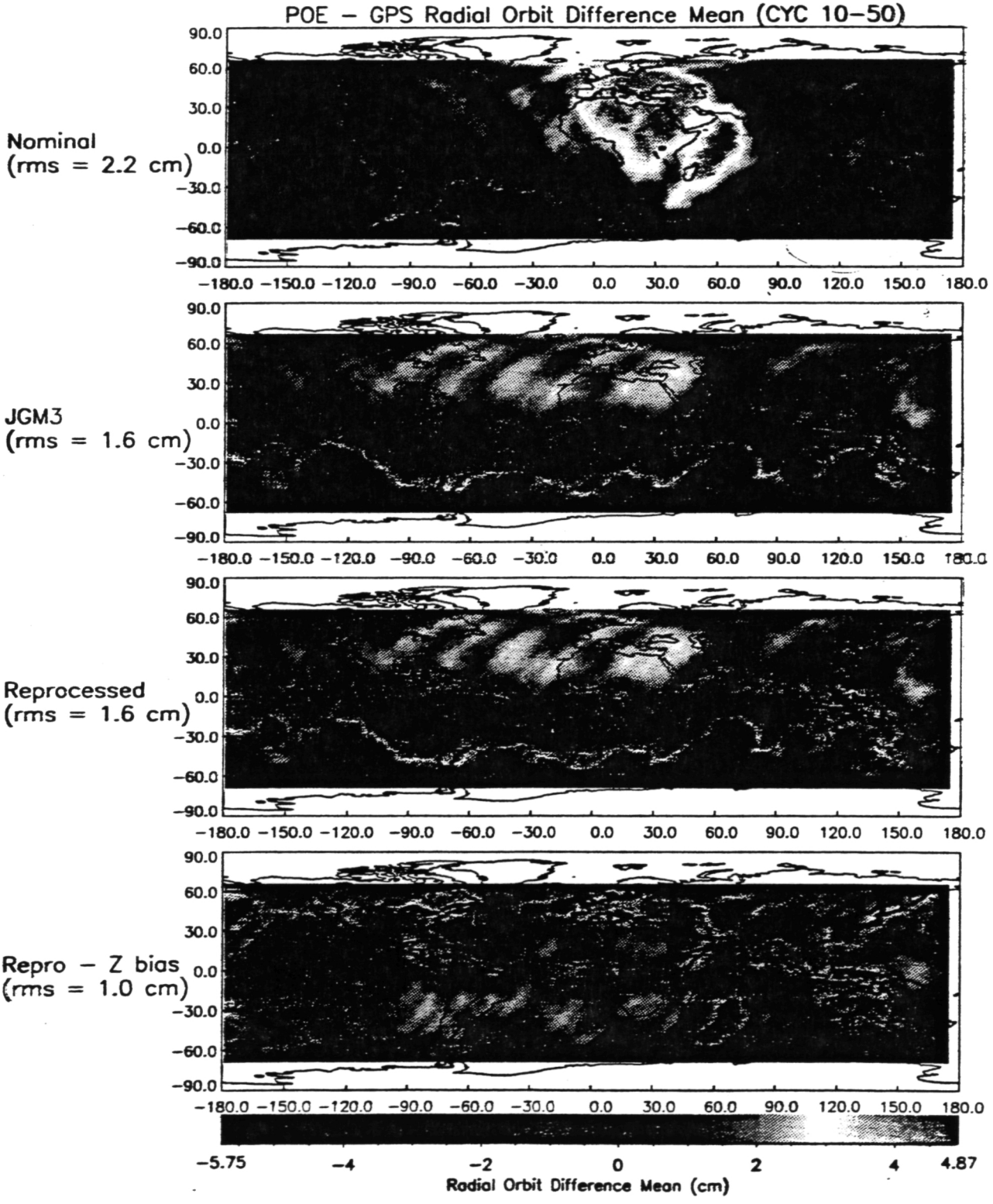
- Joint UT/GSFC model tuning the JGM-1 gravity model using additional TOPEX/ POSEIDON (GPS, Doris, SLR), Lageos-1, Lageos-2, Spot-2, and Stella data
- Improved orbit fits for TOPEX/POSEIDON (radial orbit accuracy improve to < 3 cm)
- Improved geodetic consistency for Lageos-1 & -2 (e.g., geocenter difference in x-component reduced from 36 to 4 mm)
- Improvement in Doris station positioning (from 43 mm rms to 27 mm)

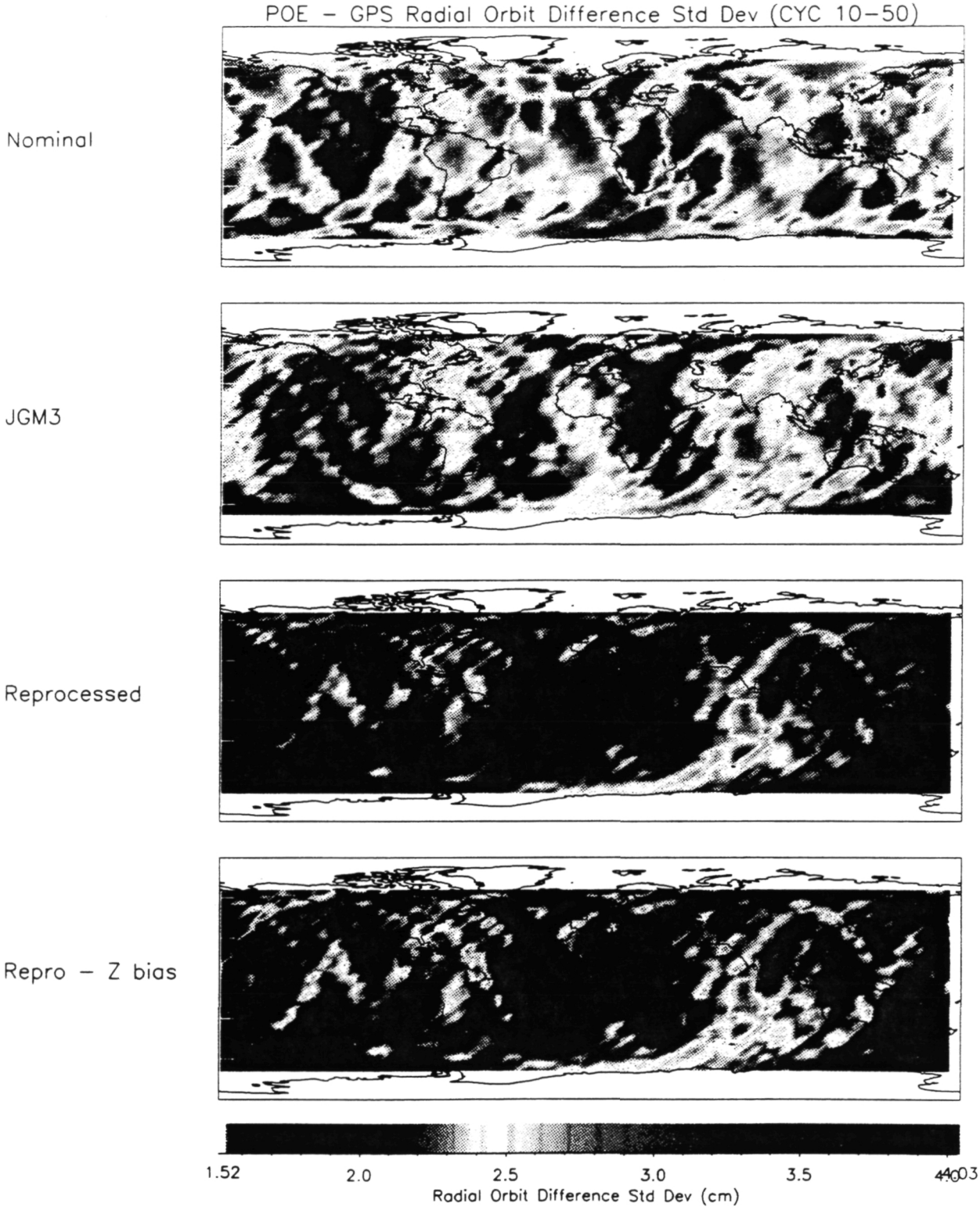
Differences between JGM-3 and JGM-2 orbits for
TOPEX/POSEIDON Cycle 45 (2.6 cm RMS)



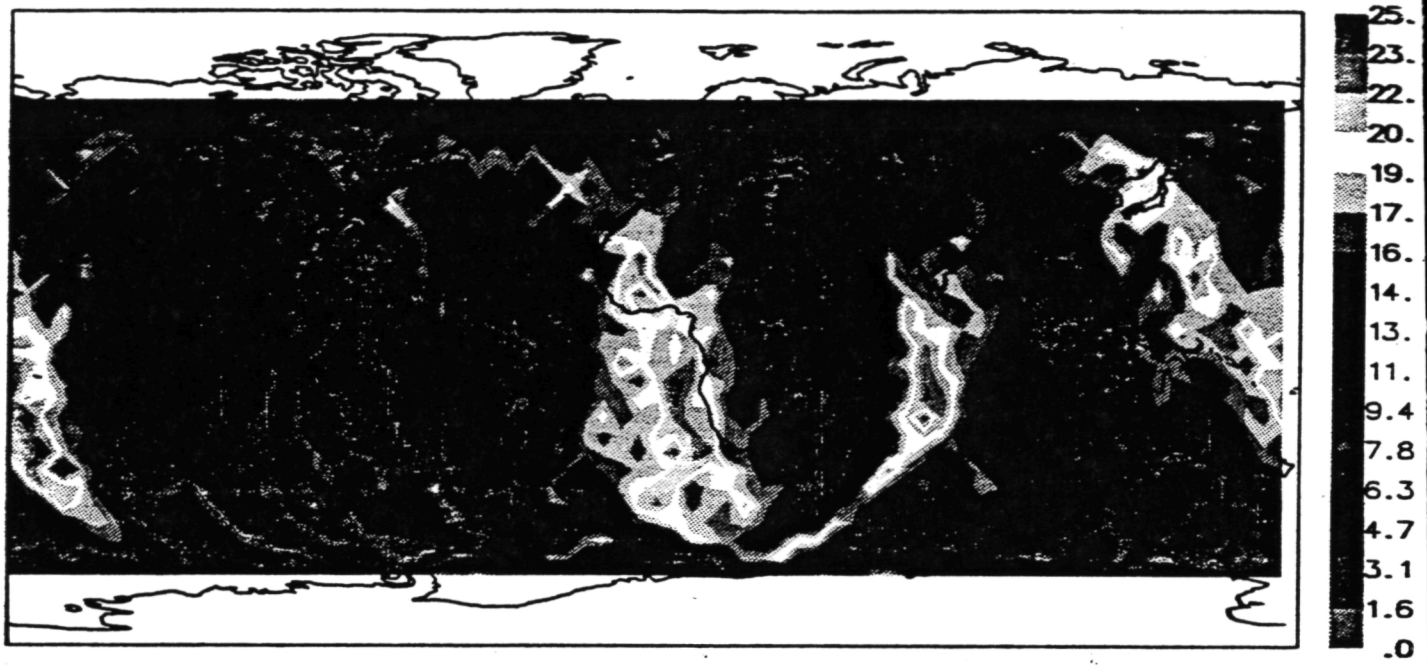
Center for Space Research

The University of Texas at Austin

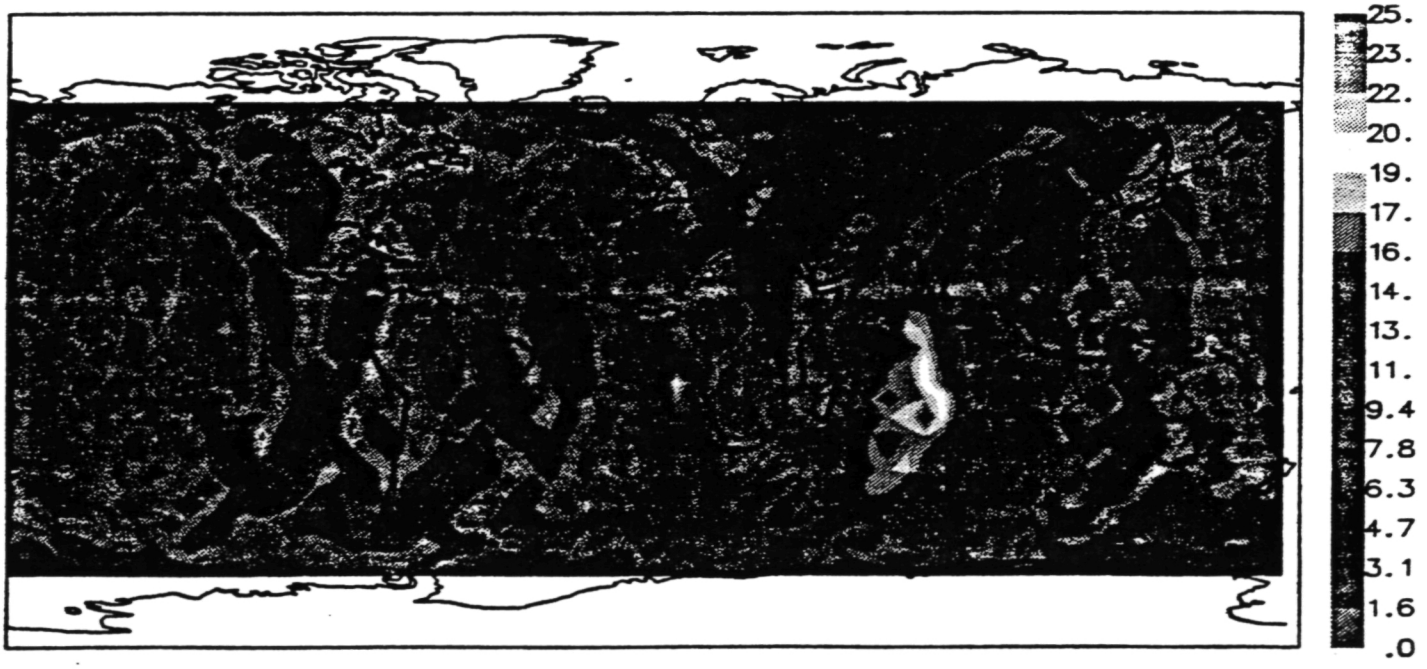

POE – GPS Radial Orbit Difference Mean (CYC 10–50)
Nominal
(rms = 2.2 cm)
JGM3
(rms = 1.6 cm)
Reprocessed
(rms = 1.6 cm)
Repro – Z bias
(rms = 1.0 cm)
90.0
60.0
30.0
0.0
-30.0
-60.0
-90.0
-180.0 -150.0 -120.0 -90.0 -60.0 -30.0 0.0 30.0 60.0 90.0 120.0 150.0 180.0
-5.75 -4 -2 0 2 4 4.87
Radial Orbit Difference Mean (cm)

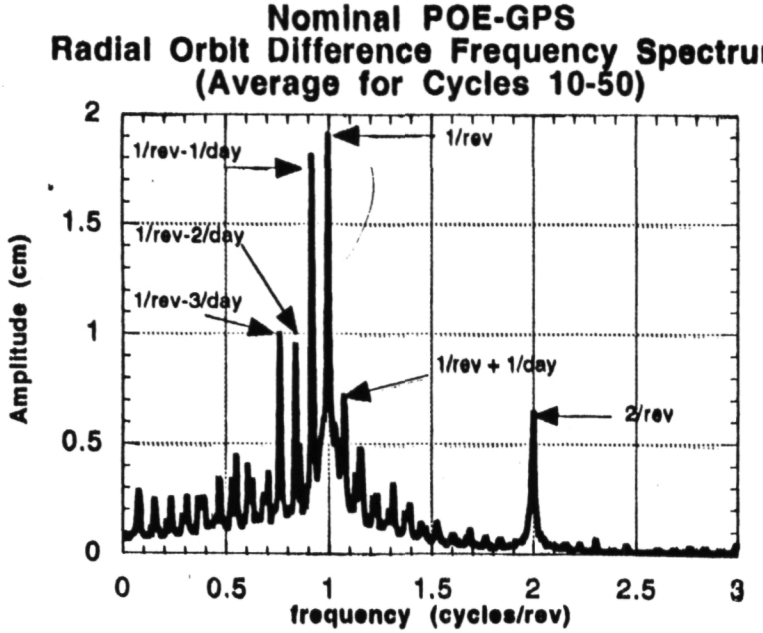

POE – GPS Radial Orbit Difference Std Dev (CYC 10–50)
Nominal
JGM3
Reprocessed
Repro – Z bias
1.52
2.0
2.5
3.0
3.5
4.03
Radial Orbit Difference Std Dev (cm)

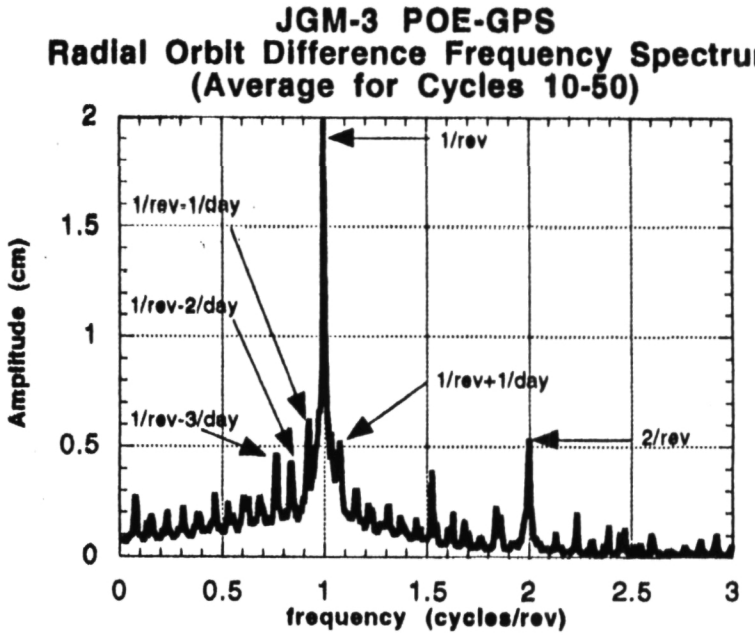
POE-GPS Col Radial Diff Spectral Anal.
Amplitude (mm) 61 day period

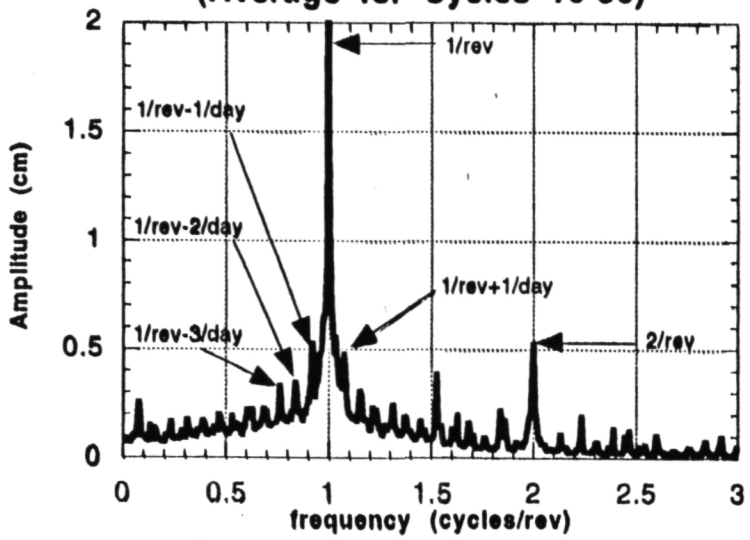


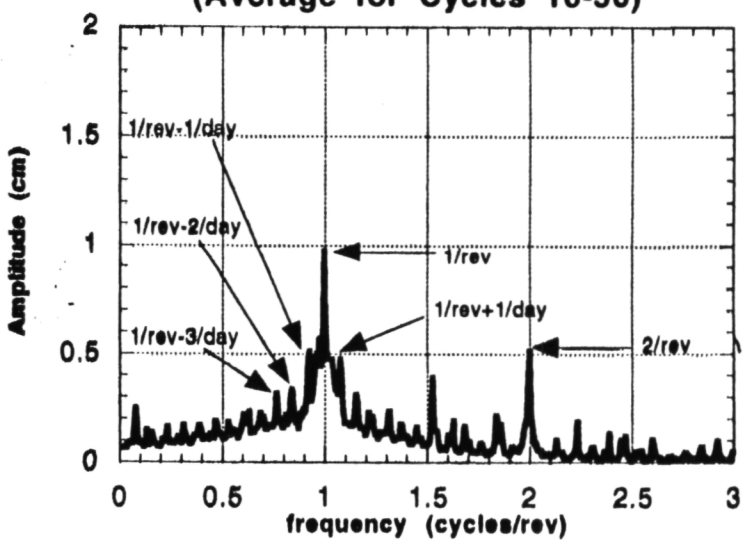
POE(BTR)-GPS Col Radl Dif Spectral Anal
Amplitude (mm) 61 day period




Nominal POE-GPS
Radial Orbit Difference Frequency Spectrum
(Average for Cycles 10-50)
Amplitude (cm)
frequency (cycles/rev)
1/rev-1/day
1/rev-2/day
1/rev-3/day
1/rev
1/rev + 1/day
2/rev


JGM-3 POE-GPS
Radial Orbit Difference Frequency Spectrum
(Average for Cycles 10-50)
Amplitude (cm)
frequency (cycles/rev)
1/rev
1/rev-1/day
1/rev-2/day
1/rev-3/day
1/rev+1/day
2/rev


Reprocessed POE-GPS
Radial Orbit Difference Frequency Spectrum
(Average for Cycles 10-50)
Amplitude (cm)
frequency (cycles/rev)
1/rev
1/rev-1/day
1/rev-2/day
1/rev-3/day
1/rev+1/day
2/rev


Reprocessed - "Z Bias" POE-GPS
Radial Orbit Difference Frequency Spectrum
(Average for Cycles 10-50)
Amplitude (cm)
frequency (cycles/rev)
1/rev-1/day
1/rev-2/day
1/rev
1/rev-3/day
1/rev+1/day
2/rev

REPROCESSED ORBIT COMPARISONS

new CSR orbits compared to new JPL reduced dynamics

T/P Cycle	Radial RMS	Transverse RMS	Normal RMS	3-D RMS	Mean X	Mean Y	Mean Z
43	1.8	6.0	9.2	11.1	-0.5	-1.3	-1.5
44	1.7	6.5	9.5	11.6	-0.9	-0.2	-0.4
45	1.5	5.9	9.3	11.1	-0.1	-0.4	0.2
46	1.9	6.8	8.9	11.4	0.8	0.0	-0.2
47	1.6	6.1	9.4	11.3	0.4	-0.1	-2.1
48	1.8	5.9	8.8	10.7	0.7	-0.1	1.4
50	1.6	5.6	7.2	9.3	-0.1	-0.1	-2.4

old CSR orbits compared to new JPL reduced dynamics

45	2.7	9.5	10.2	14.2	-1.3	-1.7	-0.4
50	2.8	9.4	8.9	13.3	-1.2	-1.4	-2.7

Notes: 1) all units cm
2) radial rms is calculated with z-bias removed; however, no rms > 2 cm
3) large normal rms reflects 3 milliarcsec rotation

TOPEX/POSEIDON ORBIT ERROR BUDGET

10 day orbits, estimate empirical acceleration parameters

Error Source	Current POE (cm)	Reproc. orbits* (cm)	Future Best** (cm)
Gravity (static component)	2	1	<1
Rad. pressure (solar, terrestrial, and thermal)	2	2	1
Atmospheric drag	<1	<1	<1
GM (gravitational constant)	1	1	1
Time variable gravity	1.5	1	<1
Terrestrial reference frame (stations, geocenter, poles)	1	1	<1
RSS Absolute Error	<4	<3	<2

* JGM-3 gravity model and TOPEX tides ** Estimated

Reprocessed orbits already have 1.5-2.0 cm rms radial agreement with GPS reprocessed reduced-dynamics orbits

ESTIMATED ERROR BUDGET FOR TOPEX MEASUREMENTS OF SEA LEVEL

Error Source		Uncertainty (cm)	Decorrelation Distance (km)
Altimeter:	• Instrument noise	3.5	20
	• Bias drift	2.0	(many days)
Media	• EM bias	2.0	20–1000
	• Skewness	1.0	20–1000
	• Troposphere, dry	0.7	1000
	• Troposphere, wet	1.2	50
	• Ionosphere	2.2	20
Orbit:	**• Gravity**	**10.0**	**10,000**
	• Radiation pressure*	**6.0**	**>10,000**
	• Atmospheric drag	**3.0**	**>10,000**
	• GM	**2.0**	**10,000**
	• Earth and ocean tides	**3.0**	**10,000**
	• Troposphere	**1.0**	**10,000**
	• Station location	**2.0**	**10,000**
RSS absolute error		**13.7**	

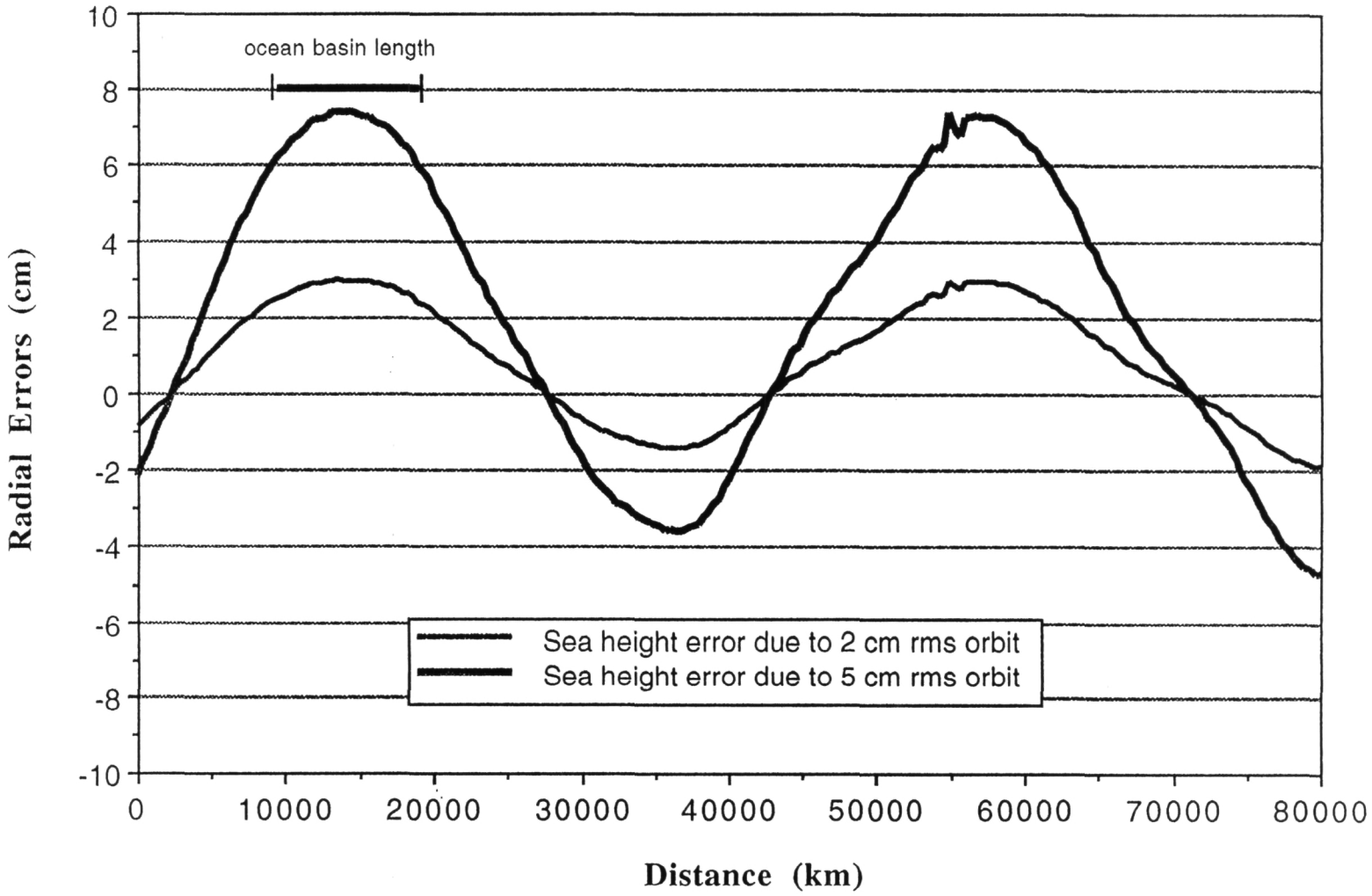
Major Assumptions

1. Dual-frequency altimeter
2. Dual-frequency radiometer
3. **15 laser tracking stations**
4. Altimeter data averaged over one second
5. $H_{1/3} = 2$ m, wave skewness = 0.1
6. Tabular corrections based on limited waveform-tracker comparisons
7. **1300 km altitude**
8. No anomalous data, no rain
9. **Improved gravity model:** postlaunch **adjustment of prelaunch** solution
10. ±3 Mbar surface pressure from weather charts
11. 100 μs spacecraft clock
12. **10-day arcs**

*Solar, Earth, and thermal radiation

CSR
CENTER FOR SPACE RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

TYPICAL ORBIT ERRORS



CONCLUSIONS

- Accuracy of reprocessed orbits is estimated to be better than 3 cm radially
  - *Minor improvements may be possible in short term with additional study*
  - *Greater orbit accuracy may be obtained with further improvement in gravity and ocean tide model, additional improvements in models for surface forces, determination of seasonal variations in gravity field, and knowledge of geocenter variations*
- Orbit accuracy better than 2 cm may be a reasonable goal
- GPS 'reduced dynamic' orbits also benefit from using improved models
  - *1.5-2.0 cm rms radial agreement between JPL and UT reprocessed orbits*
  - *Significant z-shifts still seen in some cycles and warrants continued study*
- GPS tracking offers unique orbit accuracy assessment capability, and future GPS data can be expected to be more accurate
  - *Possibility of continuing to obtain GPS data for gravity model improvement and other model improvement investigations should be pursued*

TOPEX/Poseidon SWT Position on future use of the GPS POD system: Requesting AS to be turned of by the DoD

RECOMMENDATION:

Department of Defense periodically **TURN OFF GPS anti-spoofing** (AS) for at least one 10-day period each month.

- Commensurate with defined **TOPEX/Poseidon** 10-day repeat cycles.
- For the rest of the mission.

JUSTIFICATION:

A reduction of 1-2 cm in the rms. mean sea surface error introduced by SLR and DORIS orbits may be achievable through improvements in the dynamical models and the orbit determination strategies afforded by GPS data analysis.

Such an improvement would contribute significantly to:

- Global ocean circulation modeling, and
- Analyses of the temporal variability of the ocean surface.

Altimeter Bias and Bias Drift

New SigmaO Calibration

P. Callahan

NASA Verification Results

B. Haines

CNES Verification Results

Y. Menard
P.Y. Le Traon

NASA Altimeter Internal Cal

G. Hayne.

Bias Drift Summary

S. Nerem

Discussion, Recommendations

Free-for-All

Lunch !

New TOPEX

SigmaO Calibration

Phil Callahan

December 4, 1994

Summary of results in

TOPEX/POSEIDON Research News #3

Figure 3: K Band Sigma0 Correction

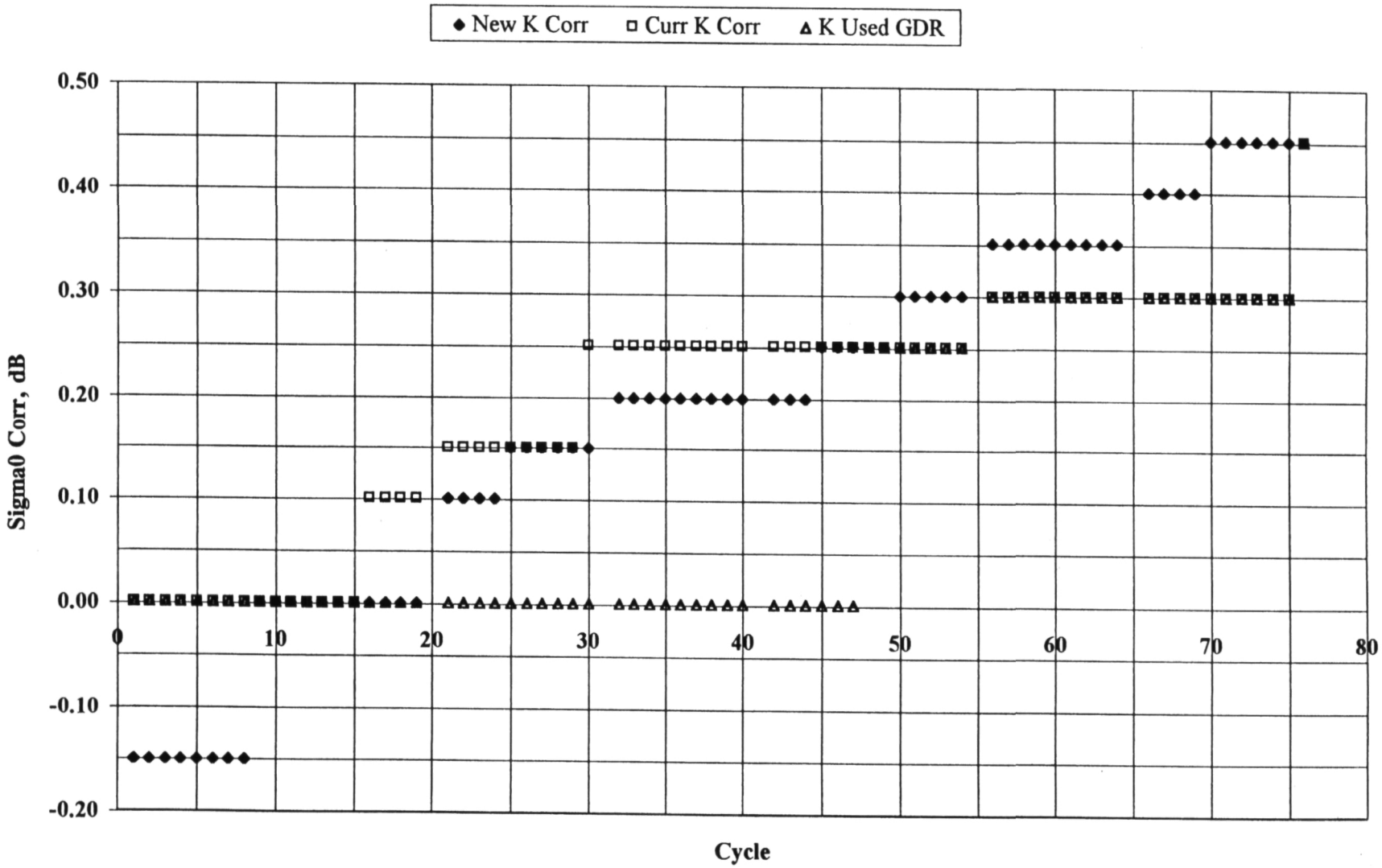
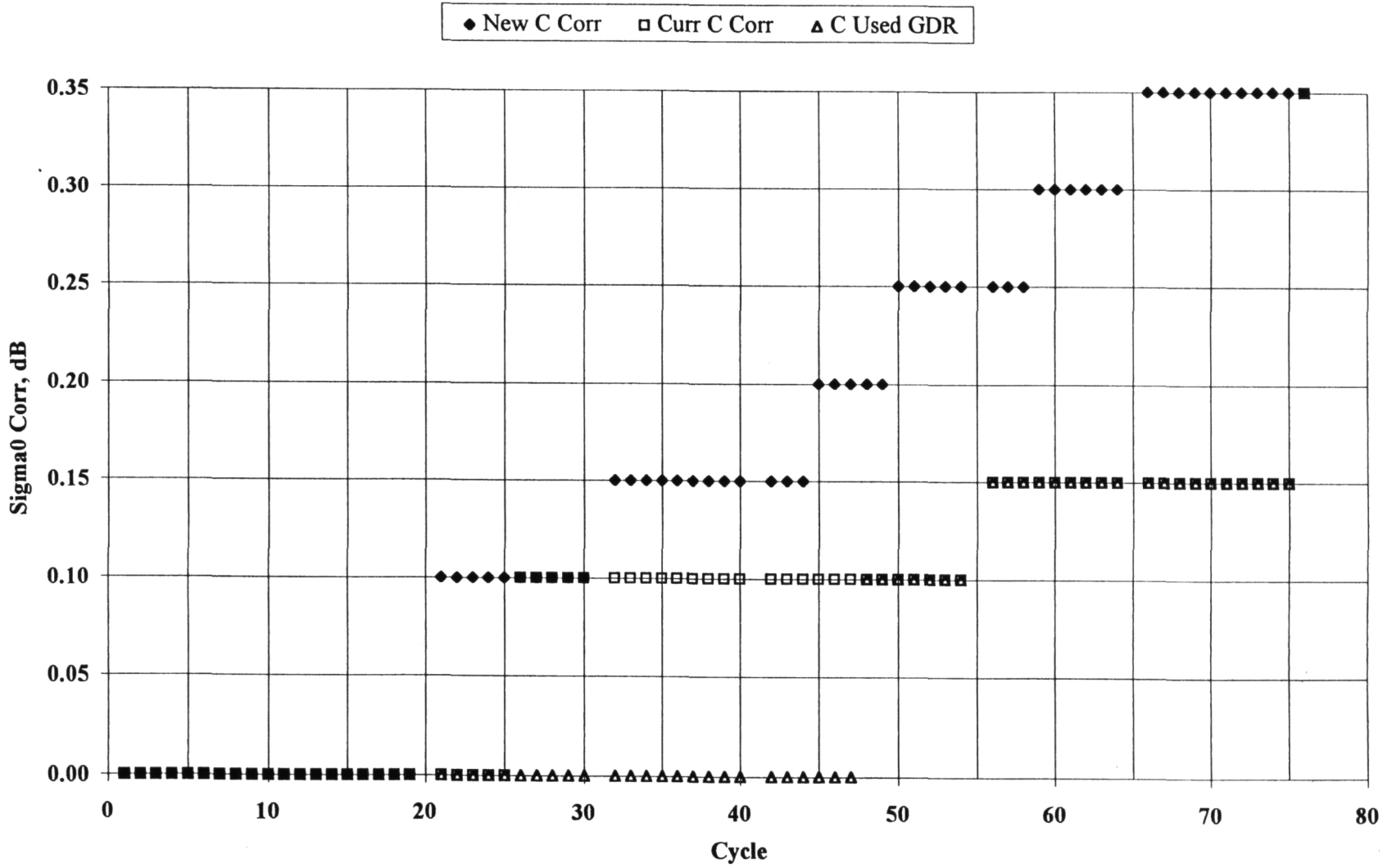
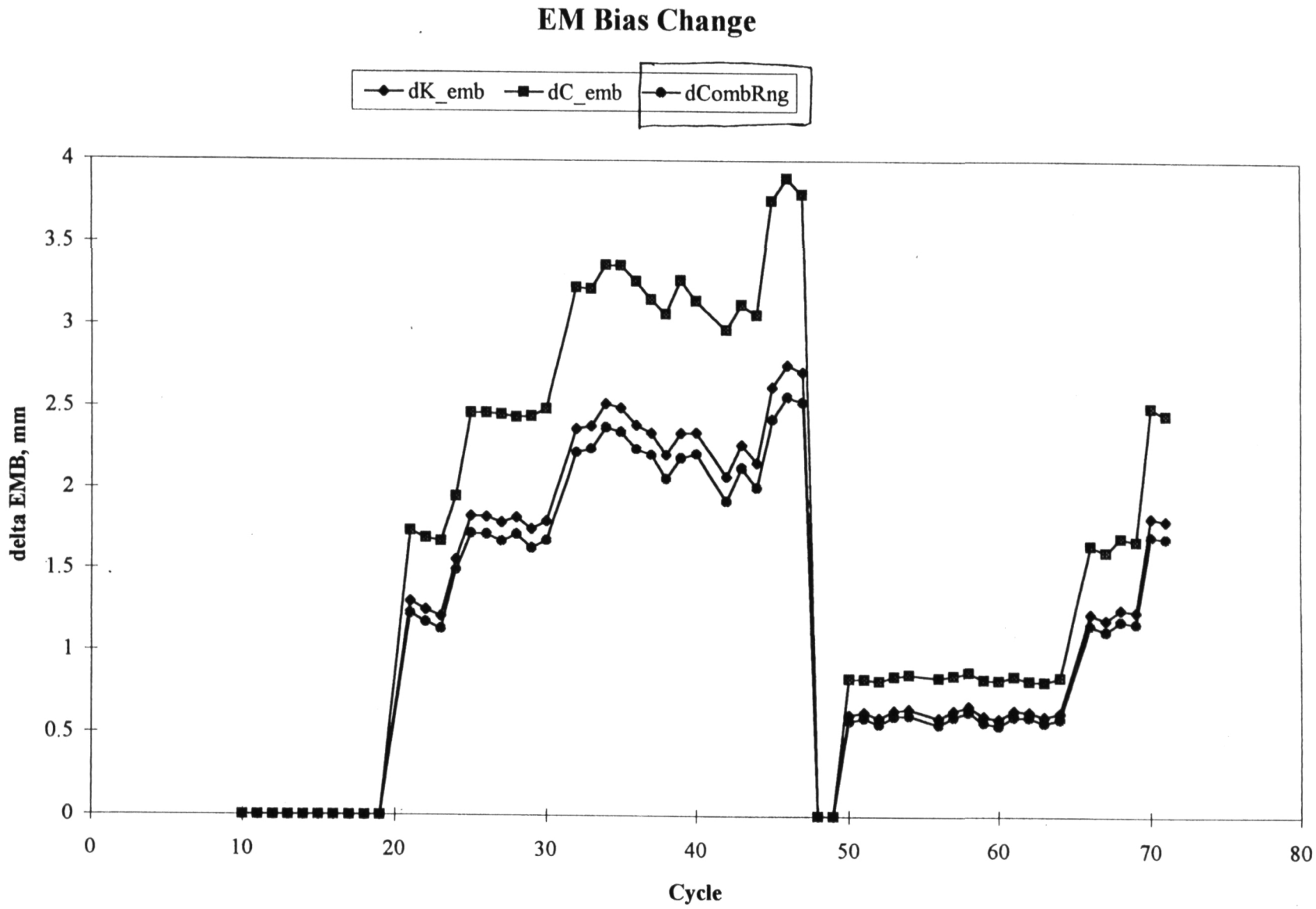
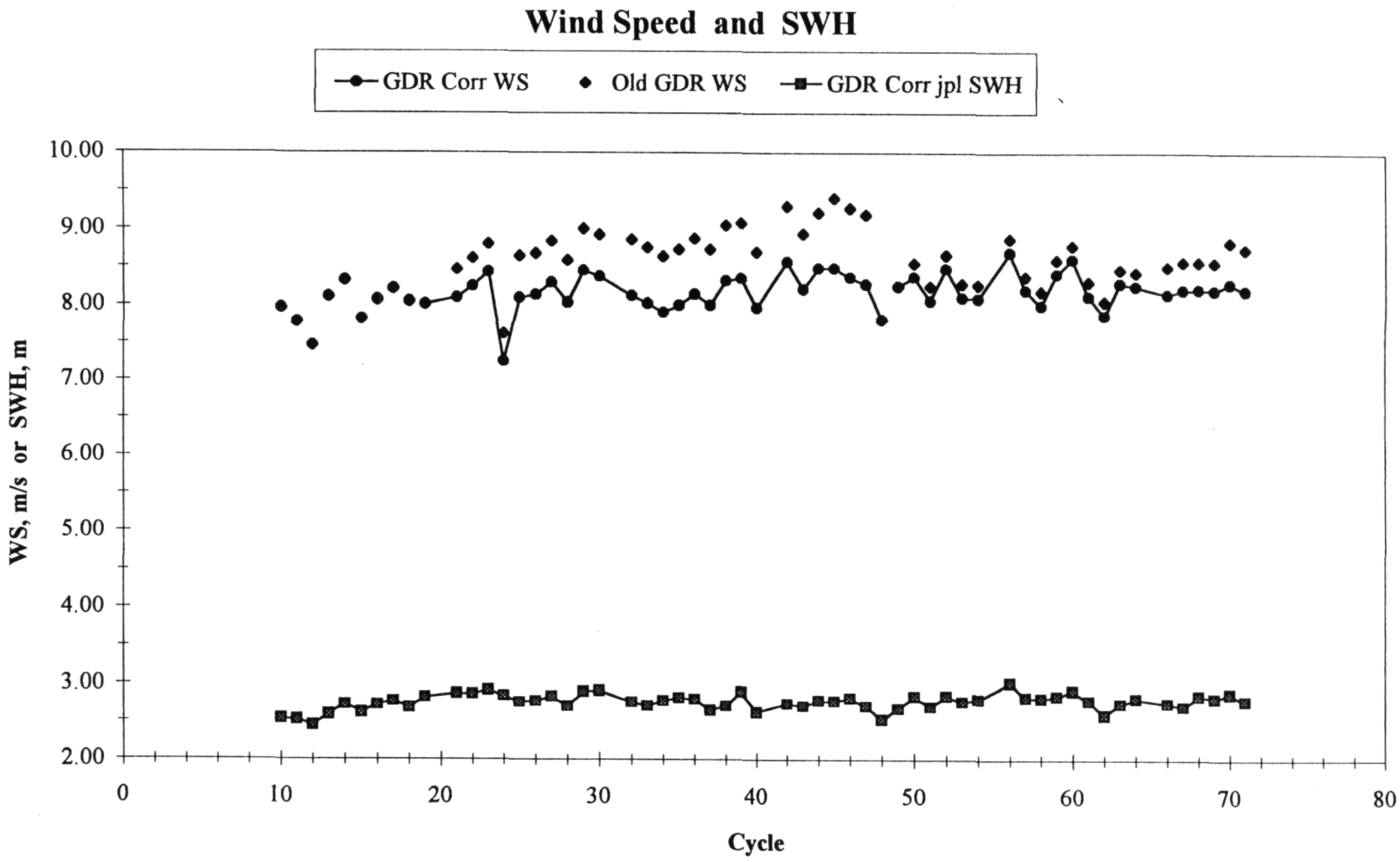


Figure 4: C Band Sigma0 Correction




EM Bias Change
dK_emb
dC_emb
dCombRng
delta EMB, mm
0
0.5
1
1.5
2
2.5
3
3.5
4
0
10
20
30
40
50
60
70
80
Cycle


Wind Speed and SWH
GDR Corr WS
Old GDR WS
GDR Corr jpl SWH
WS, m/s or SWH, m
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
0
10
20
30
40
50
60
70
80
Cycle

TOPEX - POSEIDON RELATIVE BIAS

P.Y. Le Traon - CLS Space Oceanography Group

* University of Texas tidal model
* Gaspar et al. (1994) e.m. bias (BM4) (Poseidon and Topex)

- Repeat-track analysis between Poseidon cycles and adjacent Topex cycles (2 x 400 000 data points)

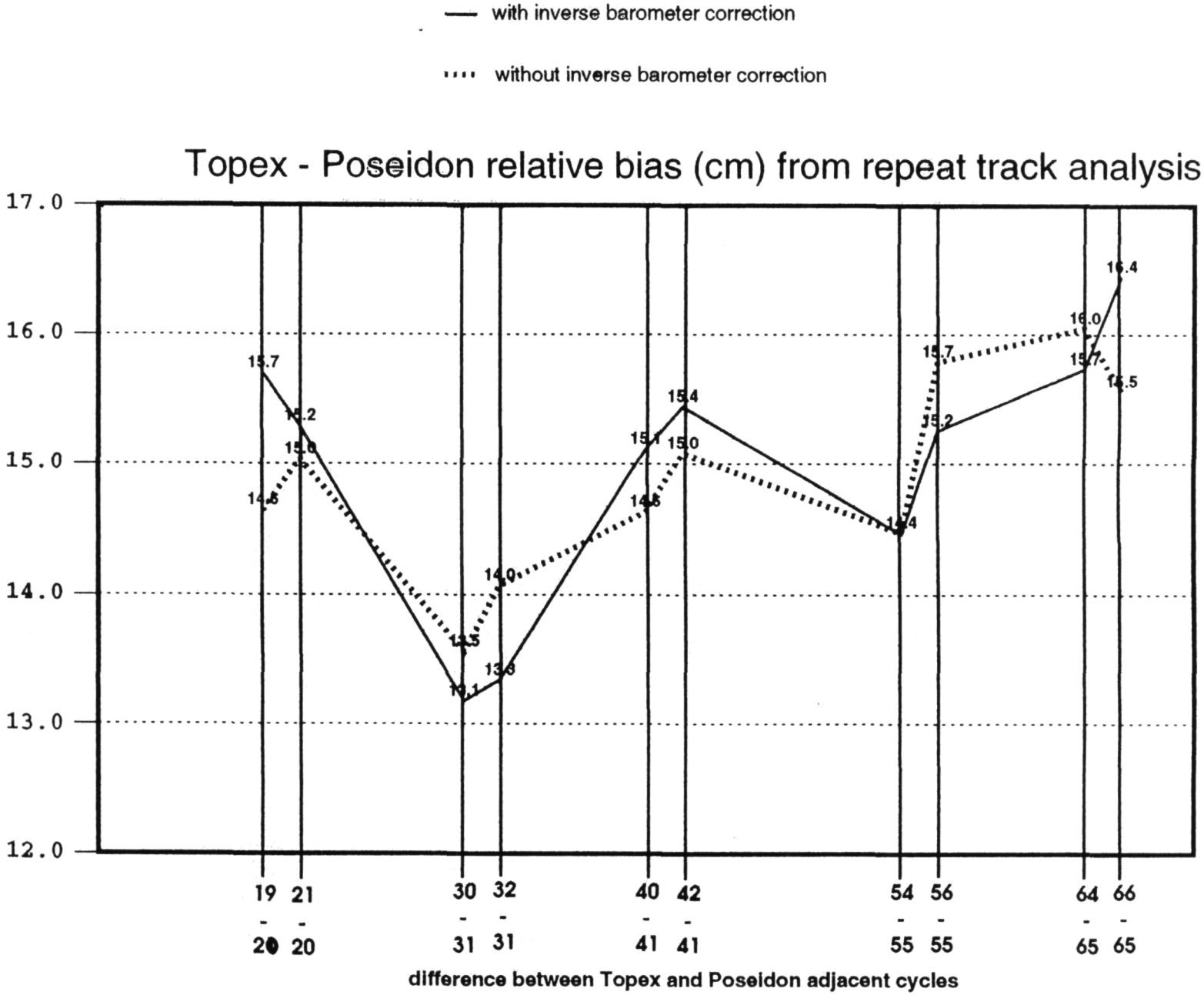
$$\begin{cases} \text{Cycle 20} = 15.5 \text{ cm} \\ \text{Cycle 41} = 15.3 \text{ cm} \\ \text{Cycle 55} = 14.9 \text{ cm} \\ \text{Cycle 65} = 16.1 \text{ cm} \end{cases}$$

- Cross-over analysis (➔ cycle 16)

~ 16 600 TP crossovers
mean of T-P = 15.5 cm

⇨ relative bias = 15.5 cm ± 0.5 cm

- Sensitive to e.m. bias correction
- The relative bias includes the bias between Topex and Doris ionospheric corrections


with inverse barometer correction
without inverse barometer correction
Topex - Poseidon relative bias (cm) from repeat track analysis
17.0
16.0
15.0
14.0
13.0
12.0
19 - 20
21 - 20
30 - 31
32 - 31
40 - 41
42 - 41
54 - 55
56 - 55
64 - 65
66 - 65
difference between Topex and Poseidon adjacent cycles

Topex/Poseidon Altimeter Calibration at Platform Harvest

E. Christensen, B. Haines, C. Morris, S. DiNardo, S. Keihm,

R. Norman, B. Wilson

Jet Propulsion Laboratory, California Institute of Technology

G. Born, M. Parke

Colorado Center for Astrodynamics Research, University of Colorado

S. Gill

NOAA/ National Ocean Service

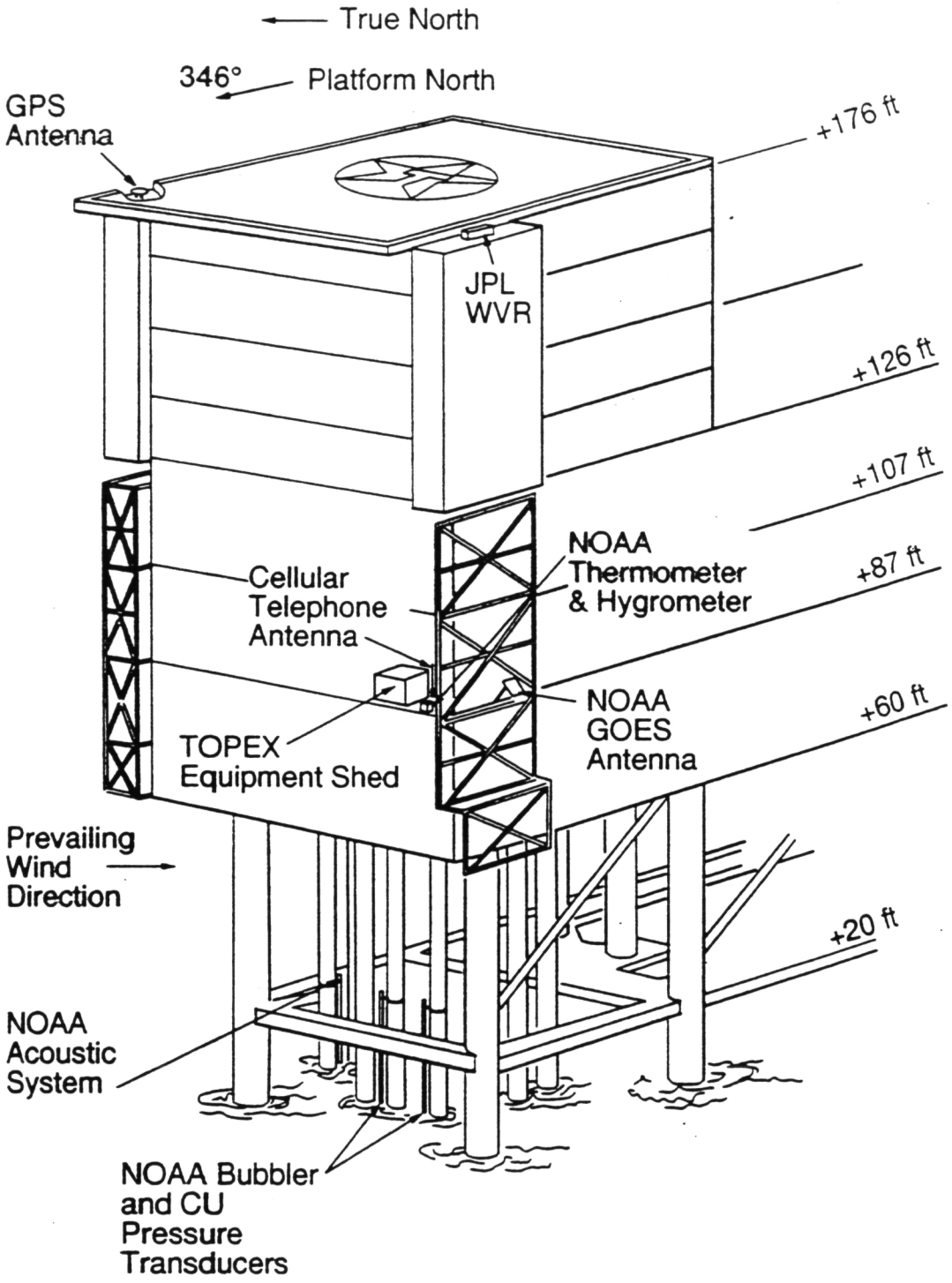
C. K. Shum, G. Kruizinga

Center for Space Research, University Of Texas

Topex/Poseidon Science Working Team Meeting

December 4, 1994

San Francisco, CA USA


True North
346°
Platform North
GPS
Antenna
+176 ft
JPL
WVR
+126 ft
+107 ft
NOAA
Thermometer
& Hygrometer
+87 ft
Cellular
Telephone
Antenna
NOAA
GOES
Antenna
+60 ft
TOPEX
Equipment Shed
Prevailing
Wind
Direction
+20 ft
NOAA
Acoustic
System
NOAA Bubbler
and CU
Pressure
Transducers

Figure

JPL

Platform Harvest Status

- 81 overflights to date

  68 Topex + 12 Poseidon + 1 safehold (Cycle 1)

- Extensive evaluation Cycles 2–36 [*Christensen et al.*, 1994]

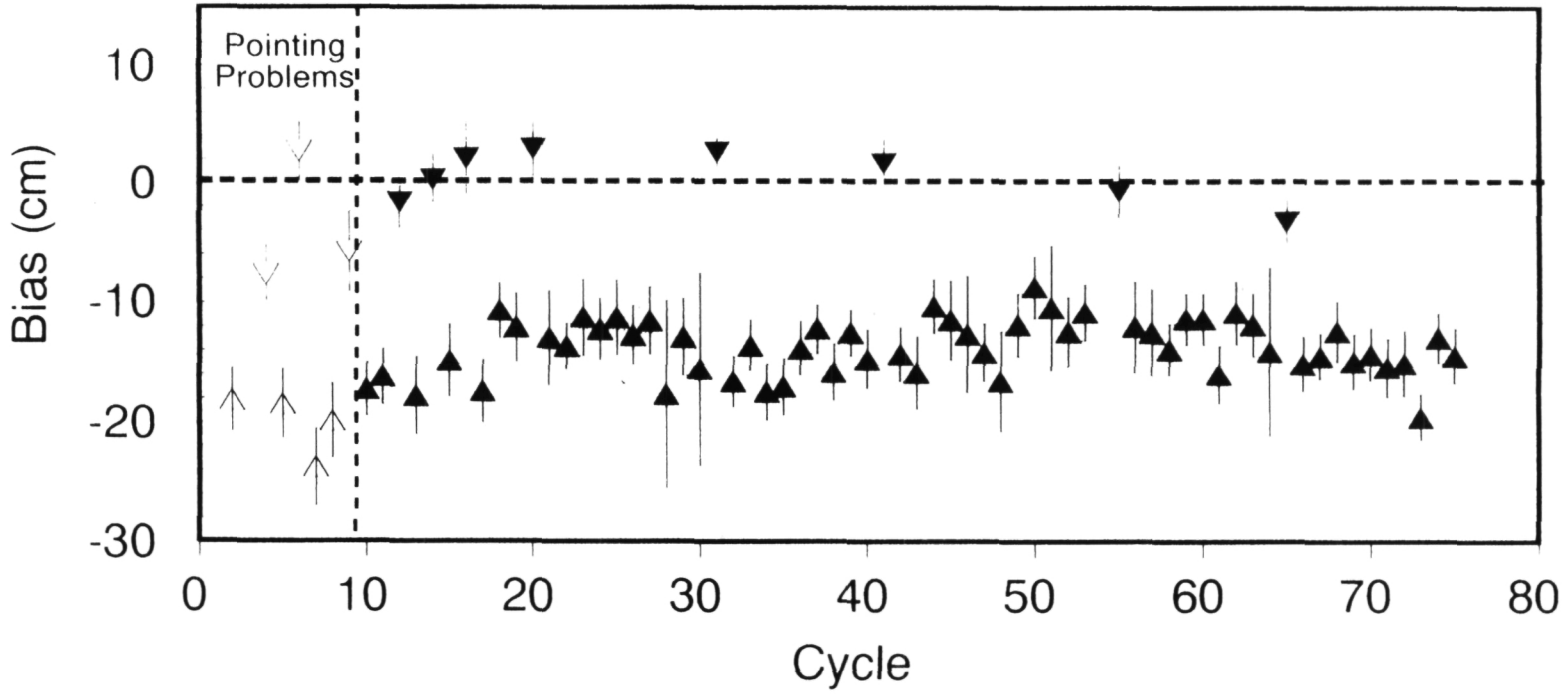
  Bias computations + WVR/Ion cal

- Extended analysis of Cycles 3–75

  Bias computations with some tide gauges

T/P Altimeter Biases from Harvest Experiment

NOAA ACOUSTIC TIDE GAUGE/GSFC JGM-3 ORBIT



▲	ALT	Mean	= -13.8 ± 0.3 cm
		Slope	= 0.1 ± 0.6 cm/yr
		σ	= 2.3 cm
▼	SSALT	Mean	= 0.1 ± 0.8 cm
		Slope	= -2.0 ± 1.7 cm/yr
		σ	= 2.2 cm

JPL

Conclusions

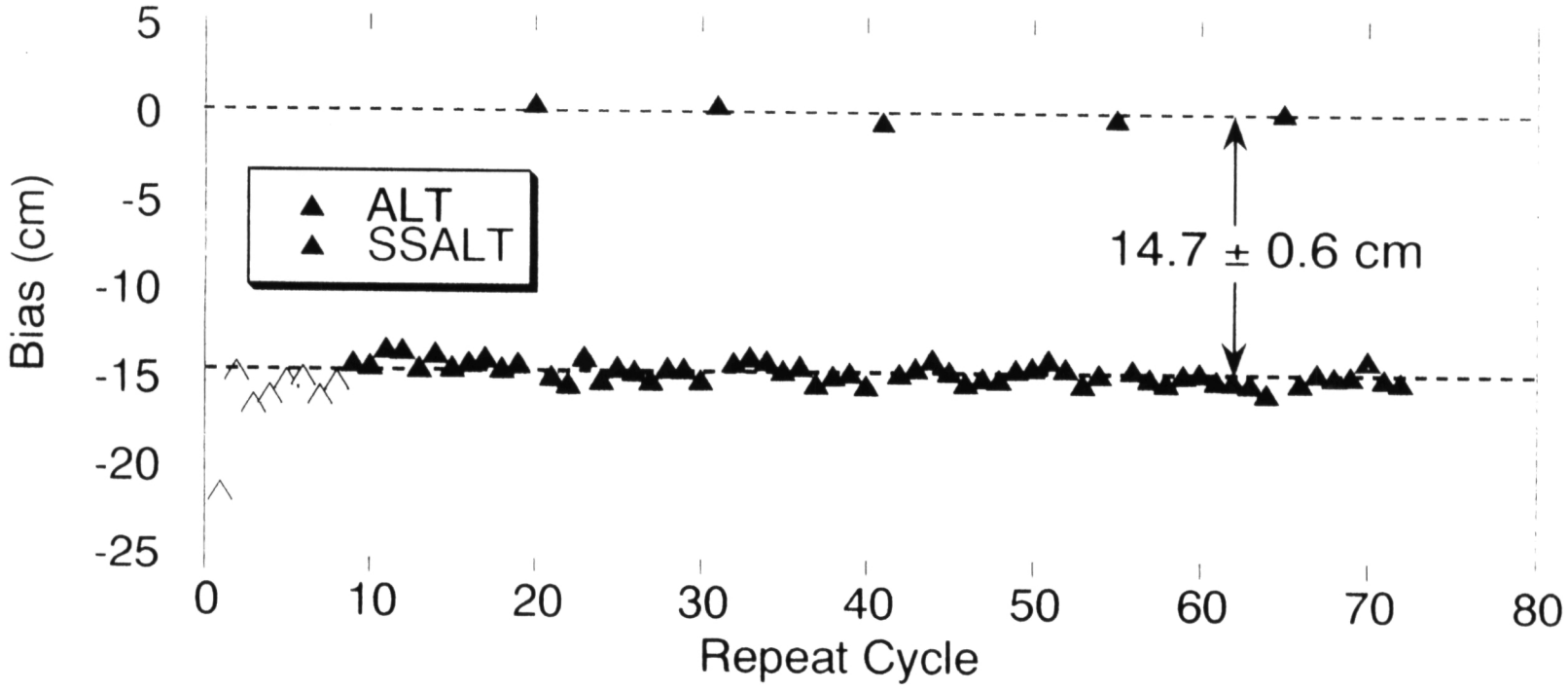
- ALT Bias estimate: -13.8 ± 3 cm
- ALT Drift estimate: 0.1 ± 1 cm/yr
- SSALT Bias estimate: 0.1 ± 3 cm
- SSALT Drift estimate: -2.0 ± 2 cm/yr
- Repeatability of the bias measurement is ~2 cm rms.
- Independent analysis of Harvest ALT Bias by *Shum et al.* yields -14.5 cm (σ = 2.9 cm).

JPL

Global Analysis

- Generate Topex (ALT) Mean Surface at Crossover Locations.
- Compute cycle-by-cycle global sea level wrt Topex mean, using latitudinal weighting scheme.
- Use JGM-3 based orbits from GSFC and *Ray et al.* [1994] tide model.
- Apply no inverted barometer correction.
- Use various EM-bias/ionosphere combinations for ALT/SSALT to assess impact on relative bias, and compare to Harvest results.

Relative ALT/SSALT Bias from Global Analysis



Parameter	ALT	SSALT
Sea State Bias	Walsh (GDR)	Gaspar-3
Ionosphere	Dual freq. ALT	Doris
Tides	Ray et al.	Ray et al.
Orbit	GSFC JGM-3	GSFC JGM-3
Pressure load	None	None

JPL

ALT/SSALT RELATIVE BIAS

Comparison of Platform and Global Results for Different Sea-State Bias Models

SSB MODEL ALT	SSB MODEL SSALT	HARVEST ALT	HARVEST SSALT	HARVEST Rel.	GLOBAL Rel.
Walsh	Gaspar4	-13.8	-1.5	**12.4**	**13.7**
Gaspar3	Gaspar3	-13.7	0.1	**13.8**	**14.4**
Walsh	Gaspar3	-13.8	0.1	**13.9**	**14.7**
Gaspar4	Gaspar4	-16.2	-1.5	**14.8**	**16.0**
Walsh	Walsh	-13.8	6.4	**20.2**	**21.2**
Fu&Glz	Fu&Glz	-12.8	7.6	**20.4**	**21.5**

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JPL

ALT/SSALT RELATIVE BIAS

Comparison of Global Results for Different Ionosphere Models

ION MODEL ALT	ION MODEL SSALT	GLOBAL Rel. (cm)
Topex	Doris	**14.7**
Doris	Doris	**13.6**

JPL

ALT/SSALT RELATIVE BIAS

Sampling of results from some PO.DAAC users

Investigator	ALT SSB/ION	SSALT SSB/ION	Bias (cm)	*This Study*
Nerem et al. (GSFC)	Walsh/Topex	Gaspar4/Doris	13.6	*(13.7)*
Callahan et al. (JPL)	Walsh/Topex	Gaspar3/Doris	14.3	*(14.7)*
Shum et al. (UT)	Walsh/Topex	Shum/Doris	13.8	—

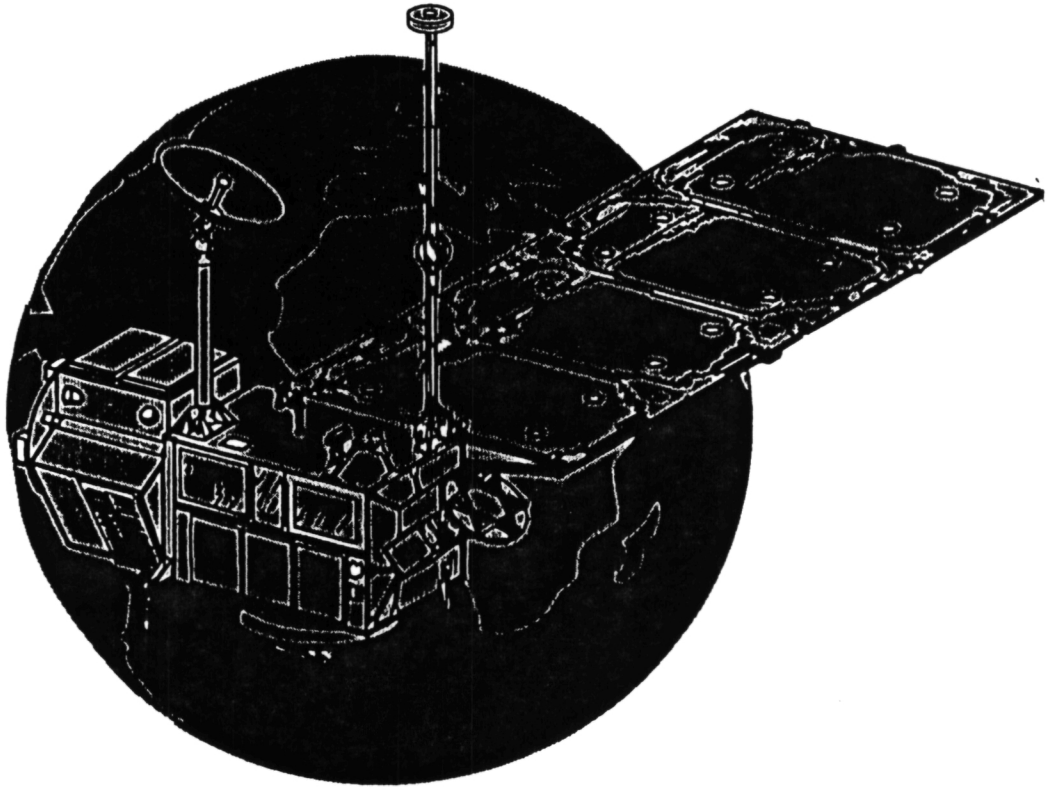
JPL

RELATIVE BIAS SUMMARY

- Nominal estimate from global analysis is 14.7 cm.
- Nominal estimate from Harvest is 13.9.
- Differences in SSB/ion models impact nominal estimate at 1-2 cm level.
- Different ocean scenes may also impact bias estimates.
- If GDR corrections used for SSB (not recommended for SSALT), relative bias is closer to 21 cm.

TOPEX/Poseidon

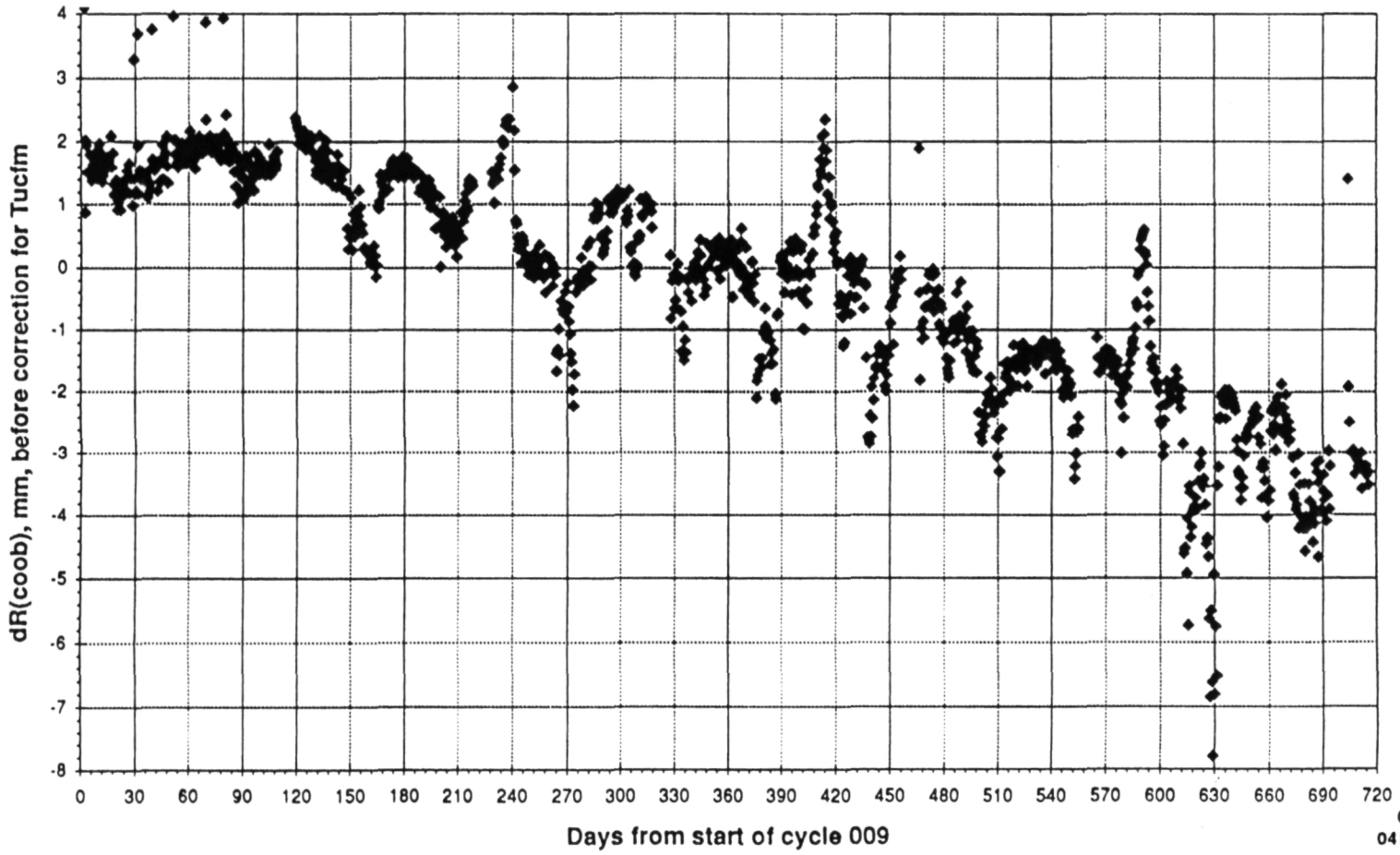
Science Working Team Meeting



TOPEX Altimeter
George S. Hayne
San Francisco, CA
December 4, 1994

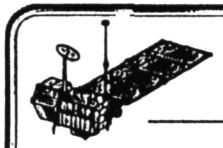
NASA
Goddard Space Flight Center
Wallops Flight Facility

TOPEX Comb (Ku&C) Delta Range from Cal-1 Step 5, Before Correction for UCFM Temperature Effect

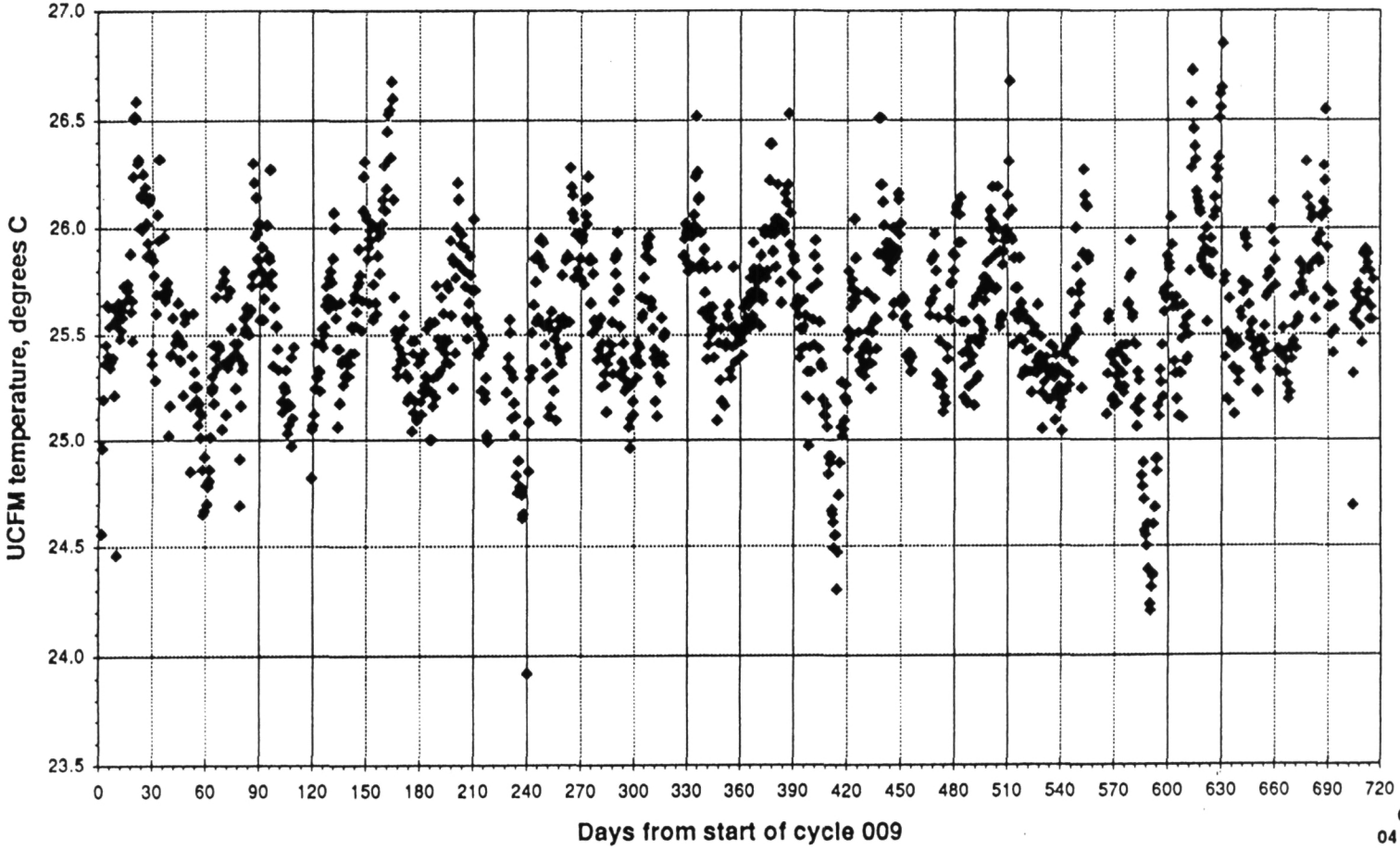


GSH
04 Dec 94

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Wallops Flight Facility



TOPEX UCFM Temperature vs Time

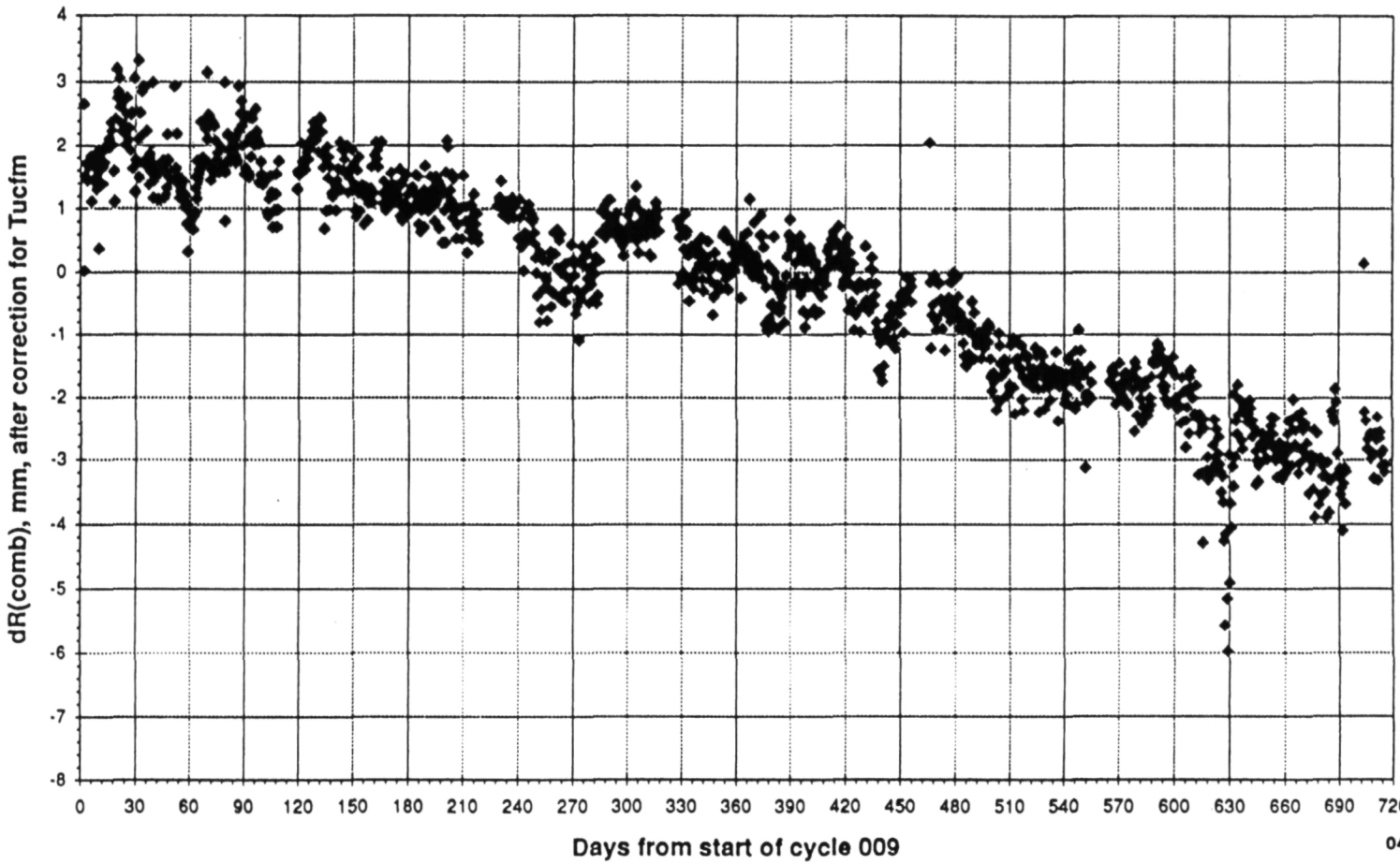


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TOPEX ALT

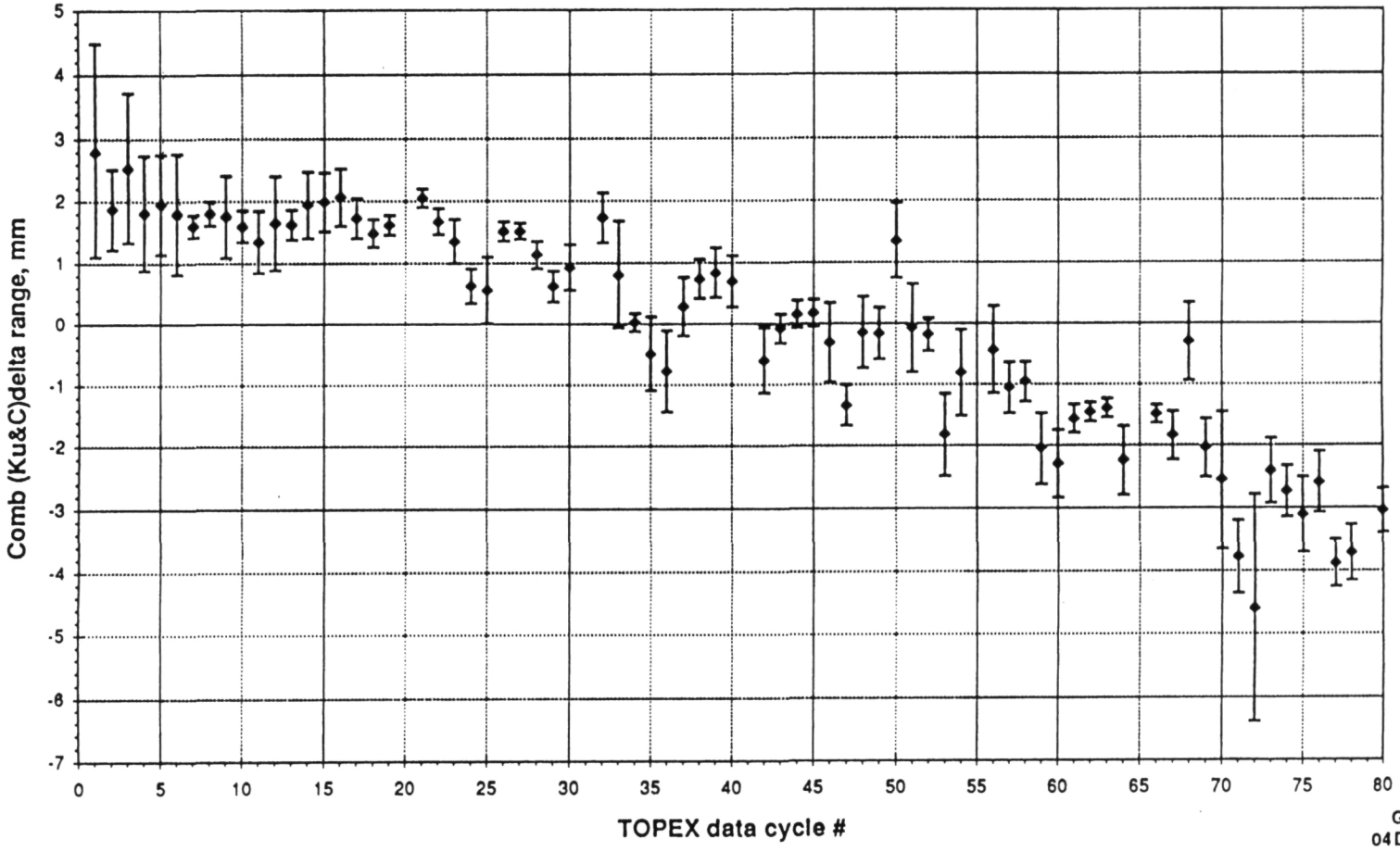
TOPEX Combined (Ku&C) Delta Range from Cal-1 Step 5, After Correction for UCFM Temperature Effect



NASA
Goddard Space Flight Center
Wallops Flight Facility

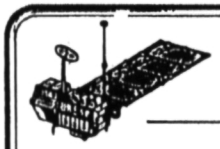
TOPEX Combined (Ku & C) Delta Range from Cal-1 Step 5

(corrected for DFB positioning quantization, but not for UCFM temperature)



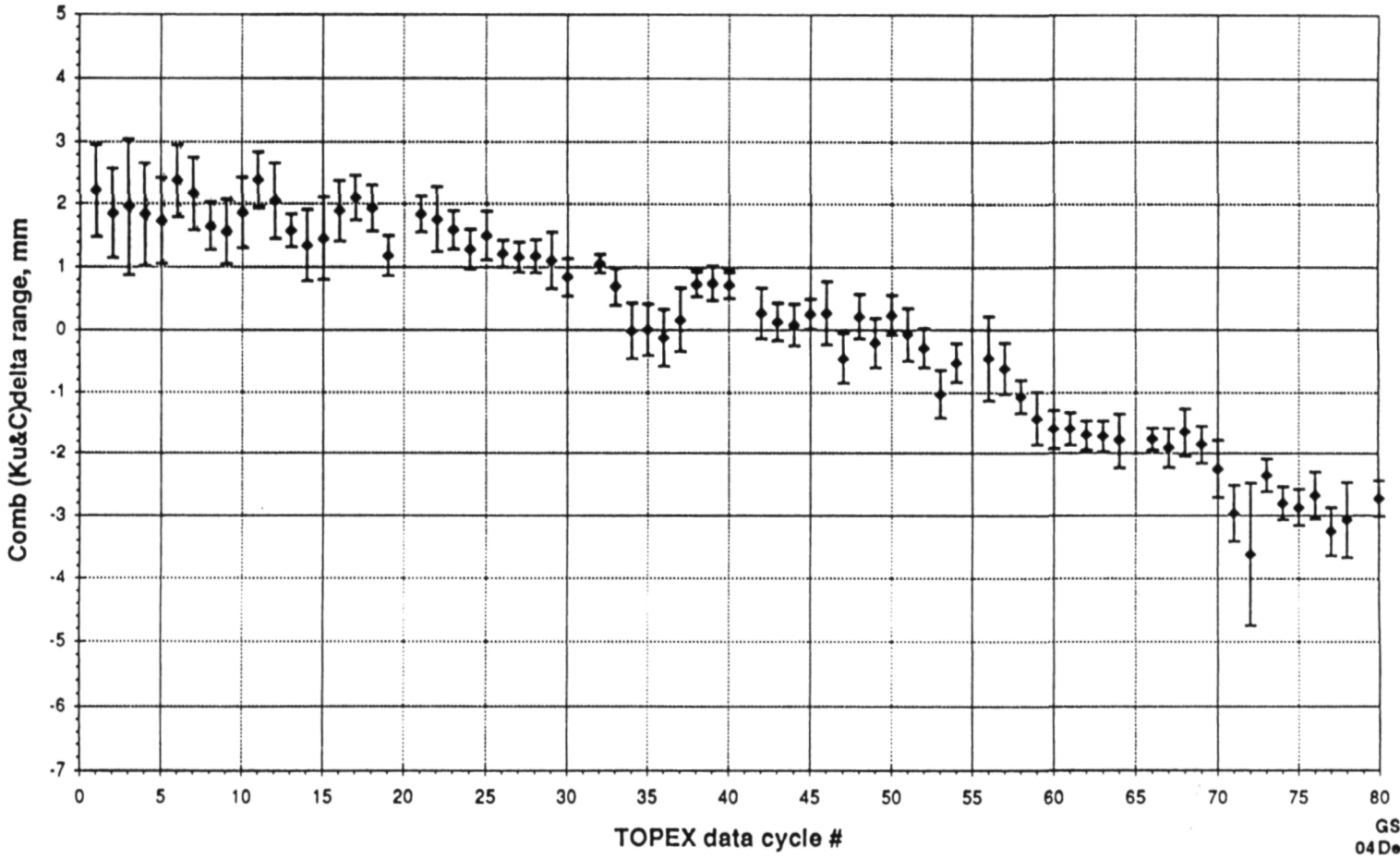
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TOPEX ALT

TOPEX Combined (Ku & C) Delta Range from Cal-1 Step 5
(corrected for DFB positioning quantization, and for UCFM temperature)



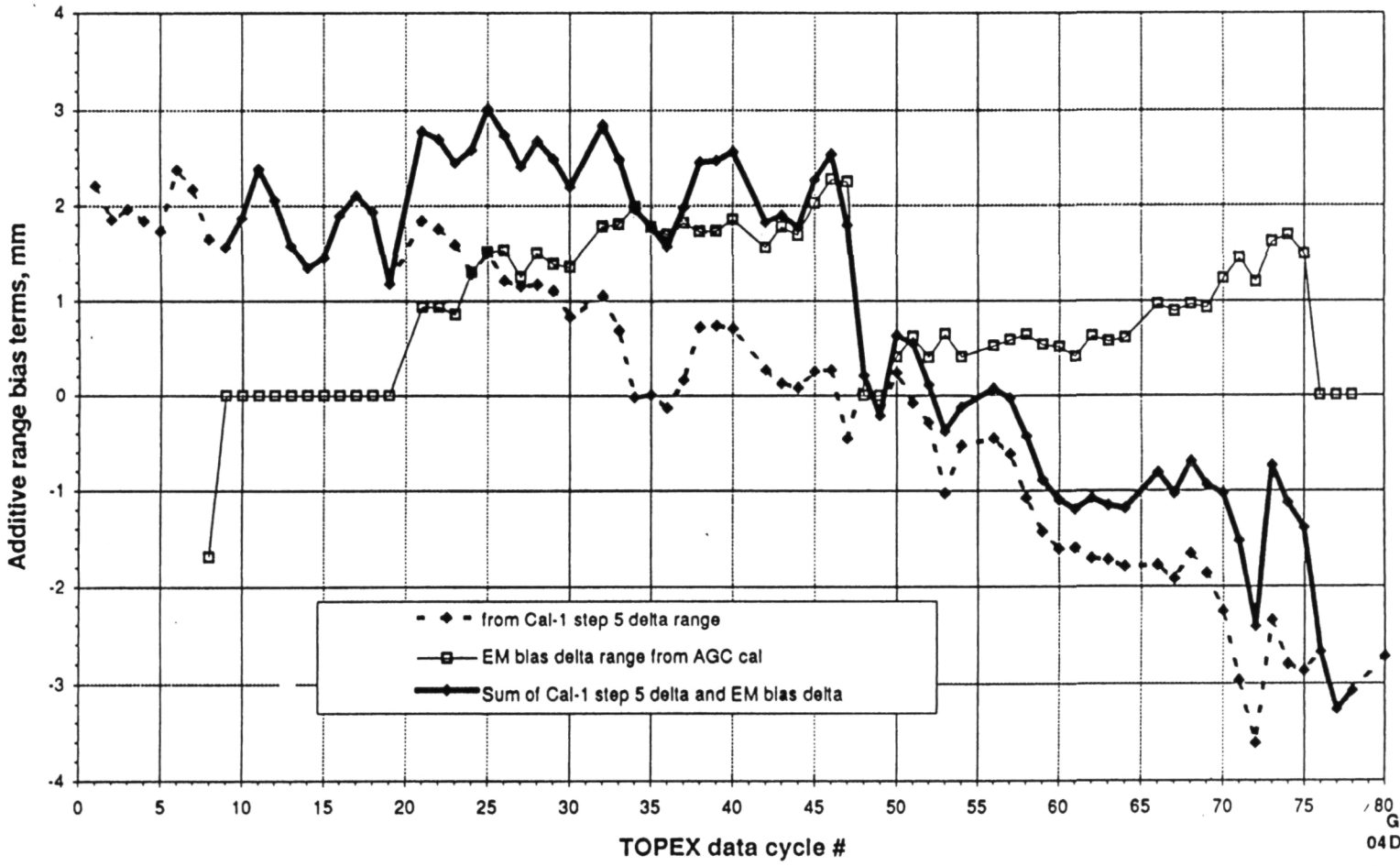
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TOPEX ALT

Contributions to TOPEX Combined (Ku&C) Range as Function of Data Cycle



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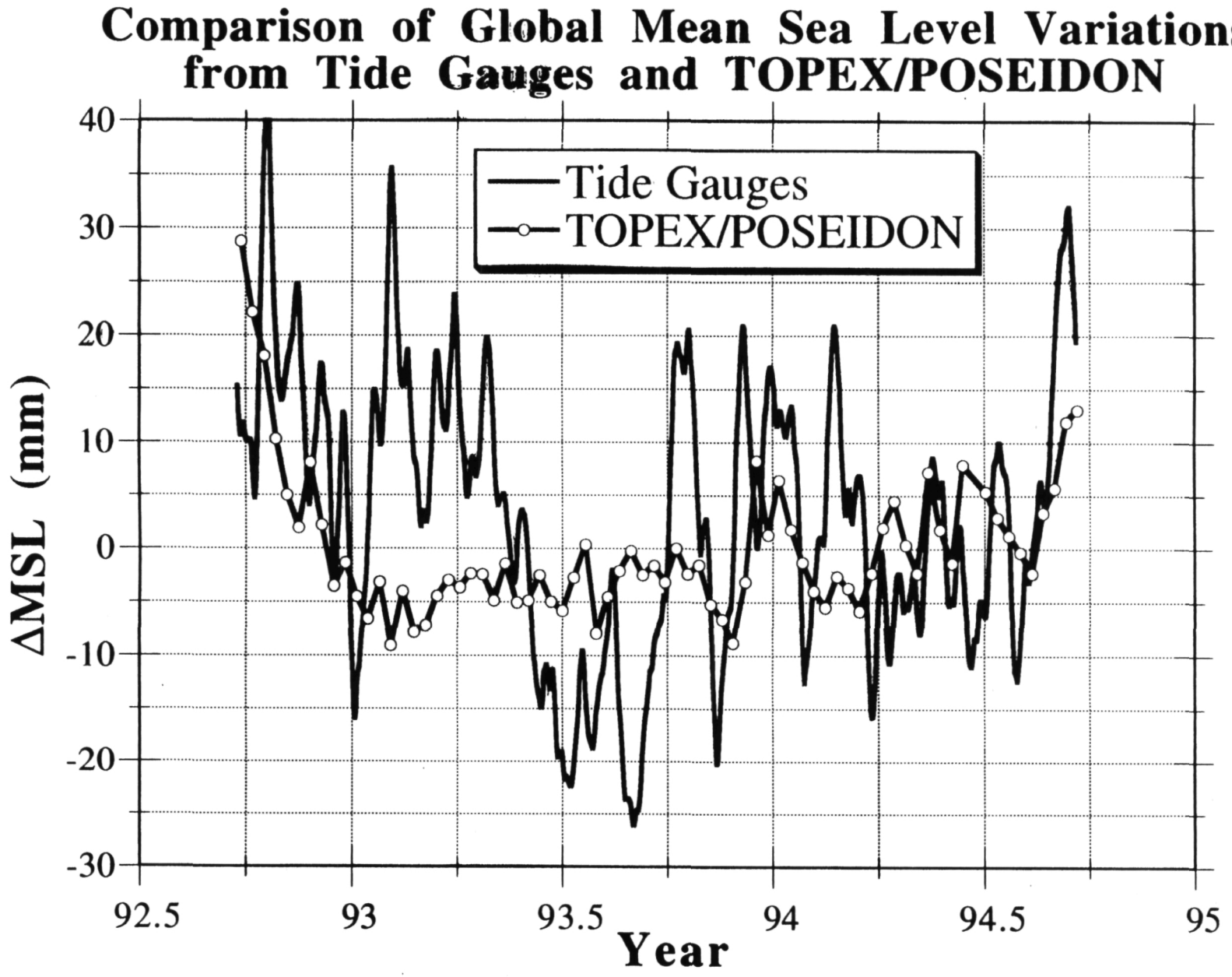
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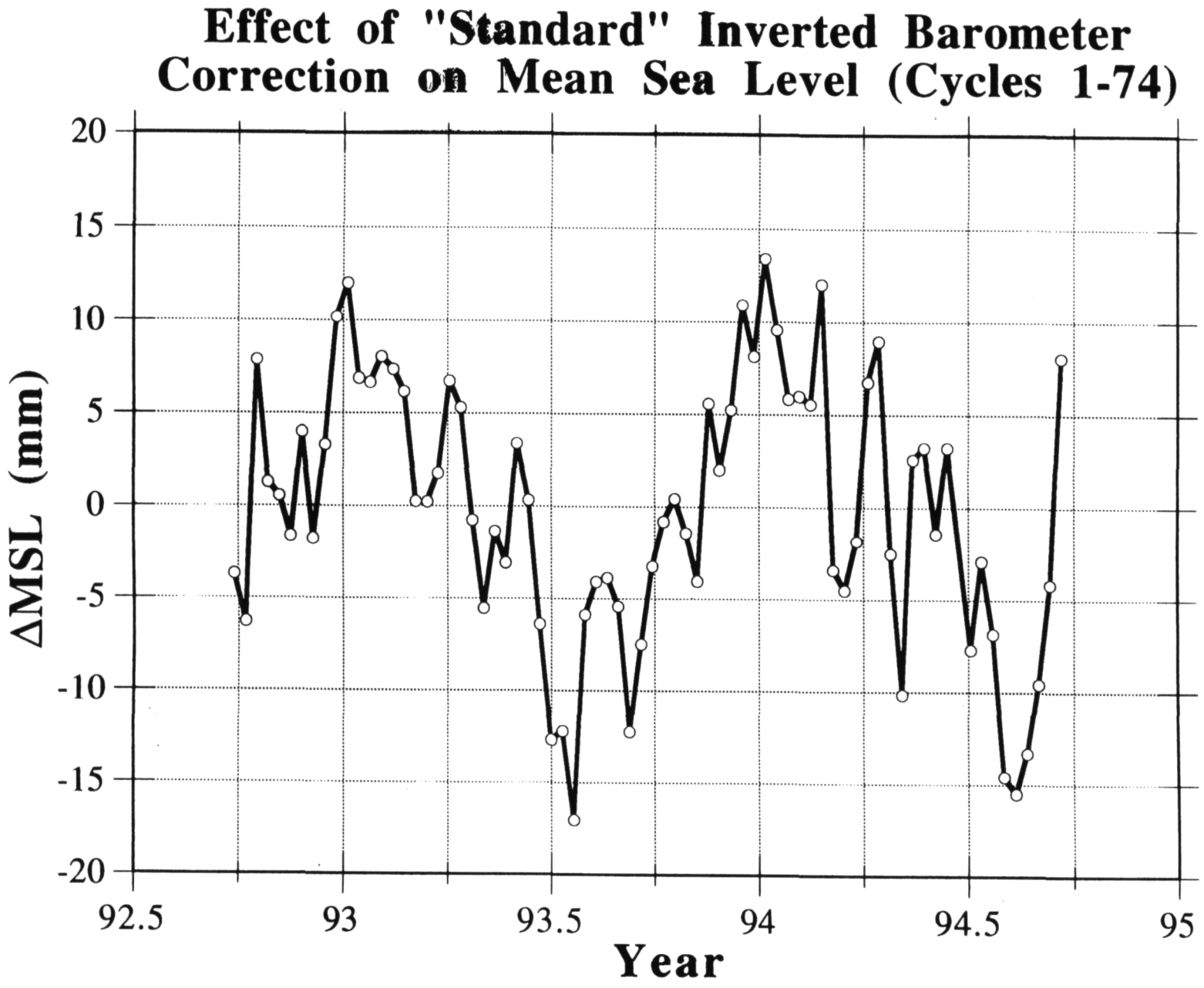
TOPEX Altimeter Drift Estimates

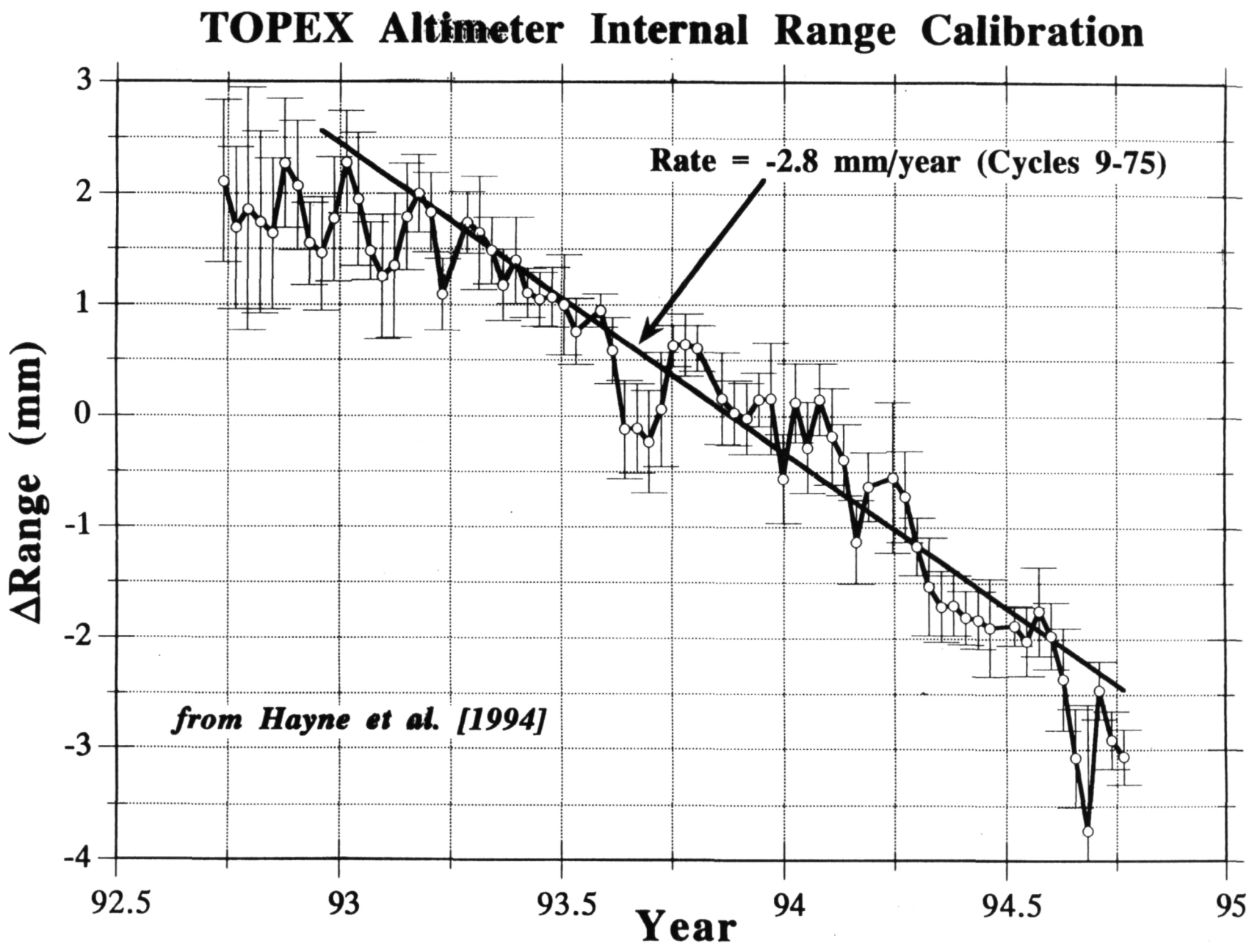
Harvest	-1 ± 10 mm/year	10-72	*Haines et al.*
Great Lakes	+9 ± 8 mm/year	9-70	*Morris & Gill*
Internal Cal	+2.8 ± 0.1 mm/year	9-74	*Hayne et al.*
Tide Gauges	-2.2 ± 12.5 mm/year	2-64	after *Mitchum*
ΔMSL	+5.7 ± 1.2 mm/year	9-74	*Nerem*
ΔMSL	+6.2 ± 1.0 mm/year	9-74	*Rapp*
ΔMSL	+3.8 ± 1.2 mm/year	9-72	*Haines*
ΔMSL	+5.8 ± 1.0 mm/year	9-74	*Wagner et al.*
ΔMSL	+1.8 ± 1.1 mm/year	9-74	*Shum et al.*

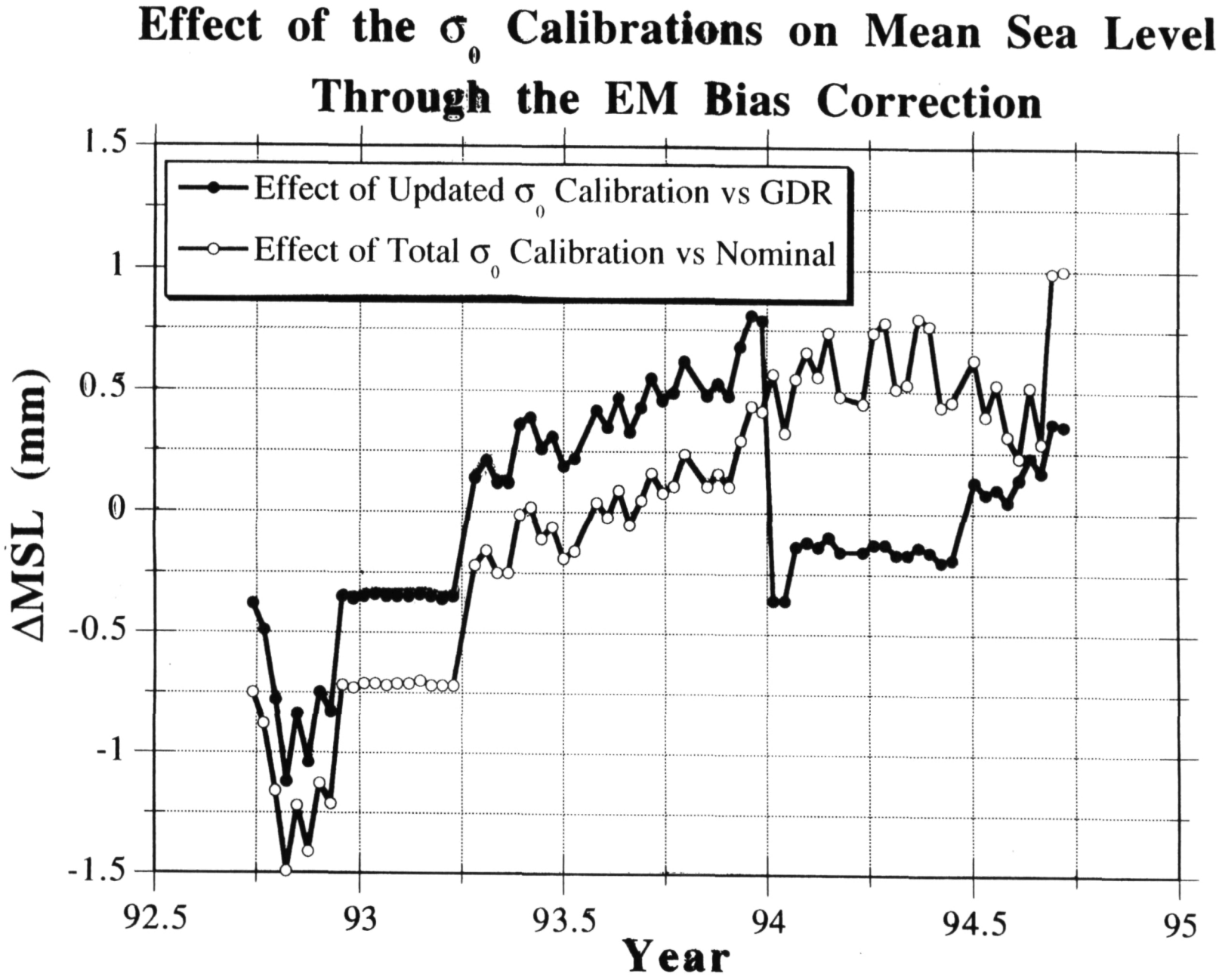
† The sign is defined such + indicates an apparent rise in sea level.

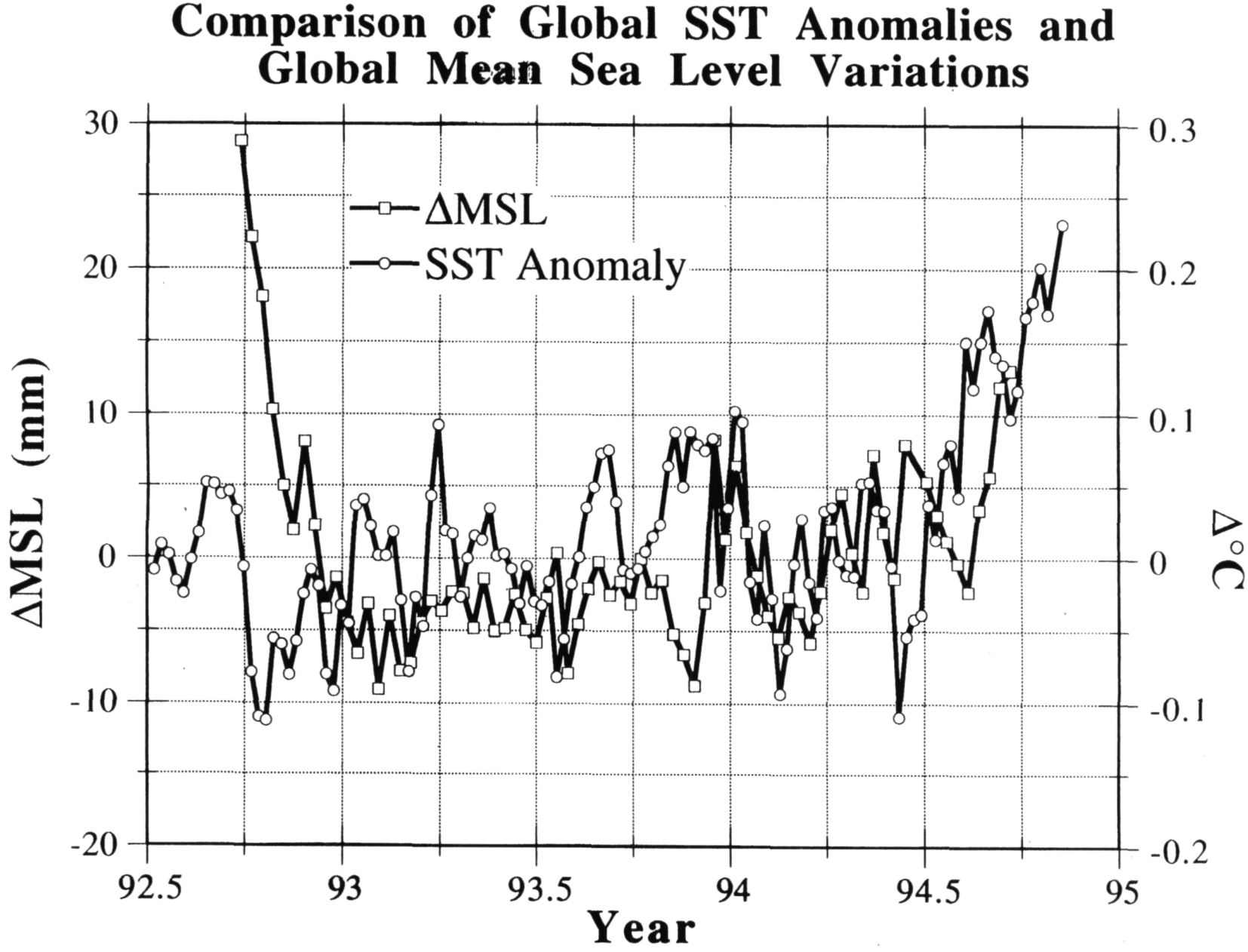
NASA | Goddard Space Flight Center
Space Geodesy Branch


Comparison of Global Mean Sea Level Variations
from Tide Gauges and TOPEX/POSEIDON
Tide Gauges
TOPEX/POSEIDON
ΔMSL (mm)
40
30
20
10
0
-10
-20
-30
92.5
93
93.5
94
94.5
95
Year

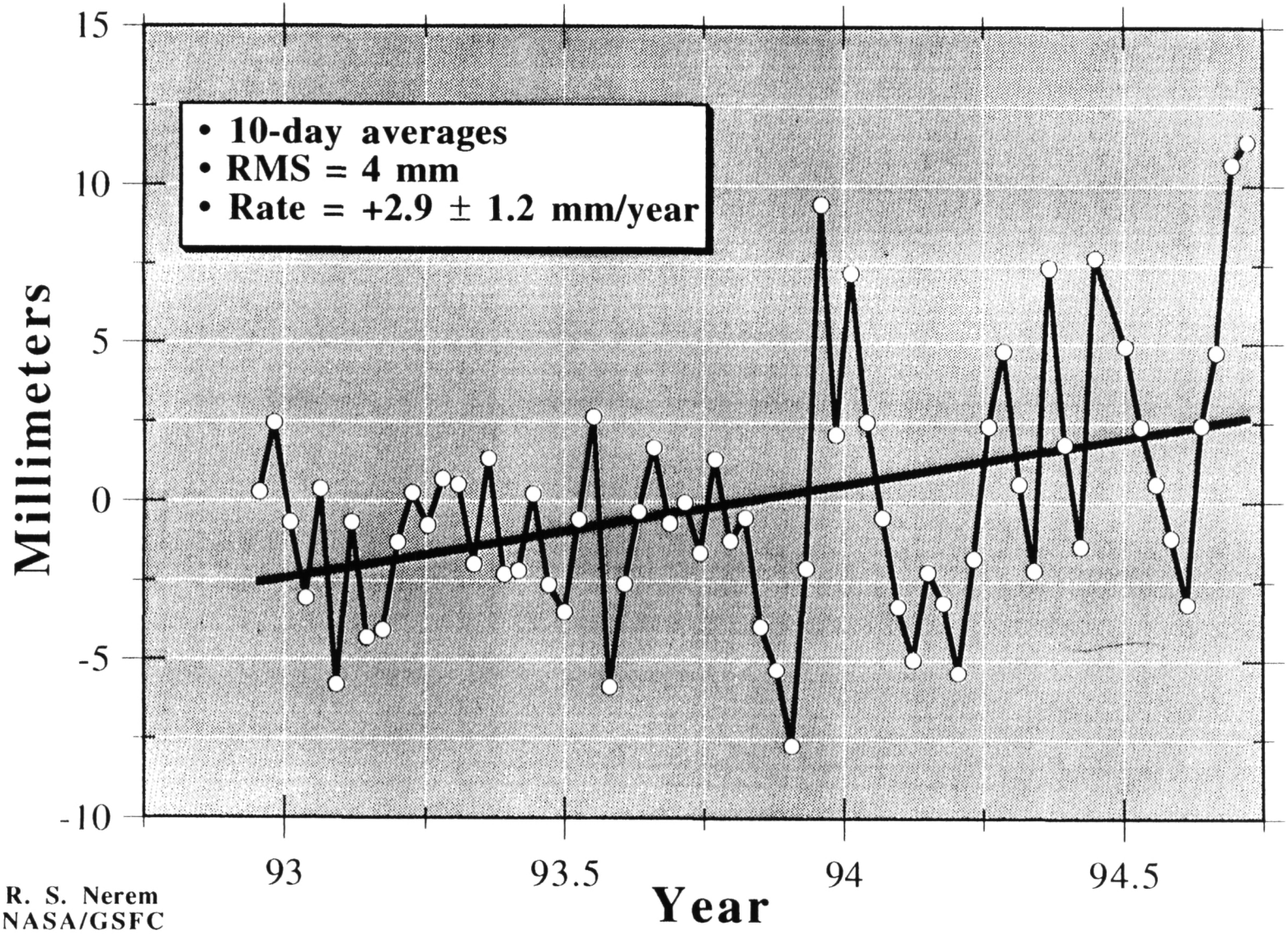

Effect of "Standard" Inverted Barometer Correction on Mean Sea Level (Cycles 1-74)
ΔMSL (mm)
20
15
10
5
0
-5
-10
-15
-20
92.5
93
93.5
94
94.5
95
Year


TOPEX Altimeter Internal Range Calibration
Rate = -2.8 mm/year (Cycles 9-75)
from Hayne et al. [1994]
ΔRange (mm)
Year
3
2
1
0
-1
-2
-3
-4
92.5
93
93.5
94
94.5
95

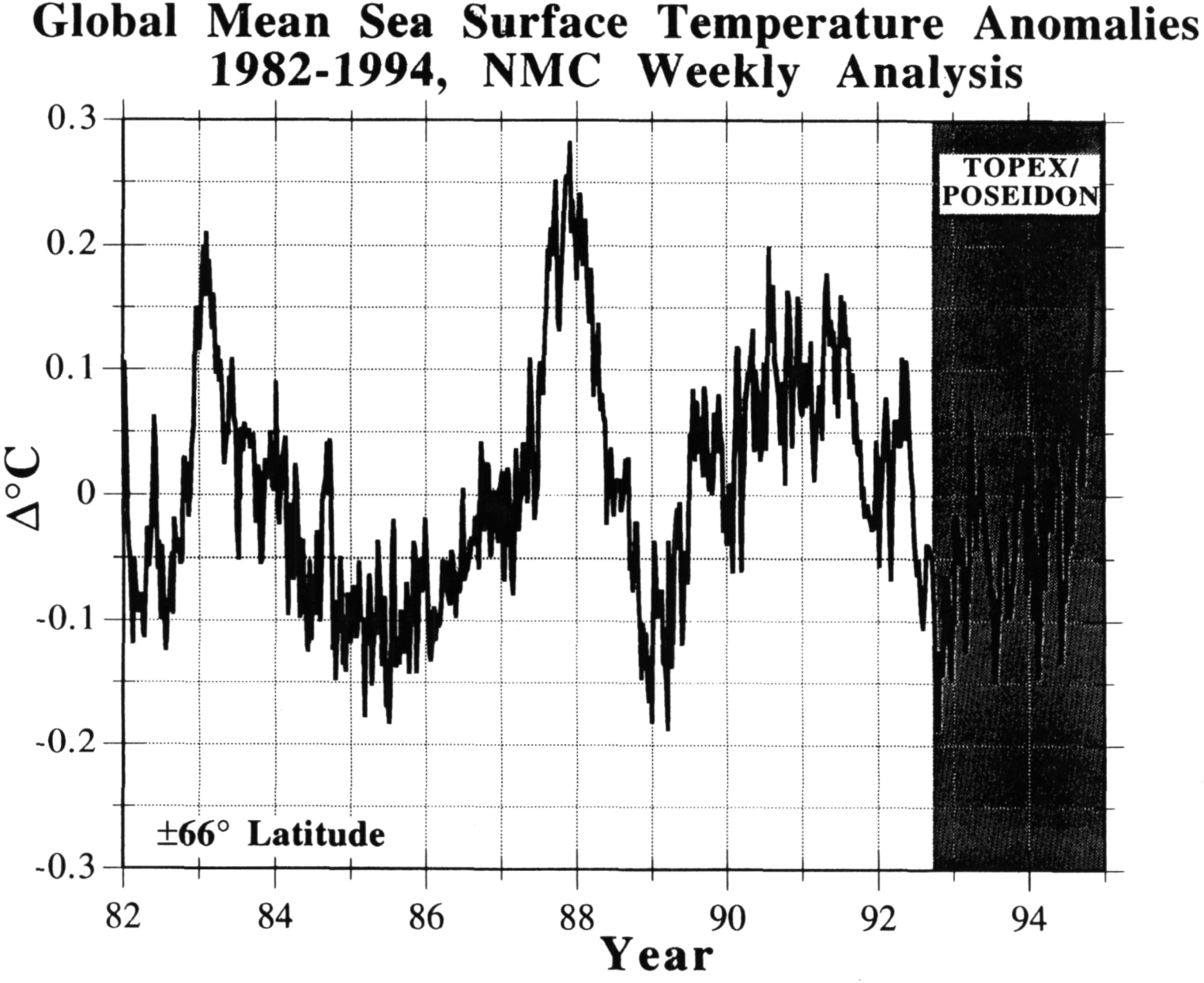

Effect of the σ0 Calibrations on Mean Sea Level
Through the EM Bias Correction
Effect of Updated σ0 Calibration vs GDR
Effect of Total σ0 Calibration vs Nominal
ΔMSL (mm)
1.5
1
0.5
0
-0.5
-1
-1.5
92.5
93
93.5
94
94.5
95
Year


Comparison of Global SST Anomalies and Global Mean Sea Level Variations
ΔMSL
SST Anomaly
ΔMSL (mm)
Δ°C
Year
30
20
10
0
-10
-20
0.3
0.2
0.1
0
-0.1
-0.2
92.5
93
93.5
94
94.5
95

Global Mean Sea Level Variations from TOPEX/POSEIDON Altimeter Data



R. S. Nerem
NASA/GSFC


Global Mean Sea Surface Temperature Anomalies
1982-1994, NMC Weekly Analysis
TOPEX/
POSEIDON
±66° Latitude
Δ°C
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
82
84
86
88
90
92
94
Year

J. M. Lemoine

GRIM4-S4/C4

GRAVITY FIELD MODELS

CNES / GRGS (TOULOUSE - GRASSE)
GFZ / DGFI (Potsdam - Munich)

SAN FRANCISCO
December 1994

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GRIM4

S4 = Satellite only
→ Up to degree 69

C4 = Combined : Satellite + Surface data (Altimetry / Gravimetry)
→ Complete to degree and order 72

SOLVED FOR :

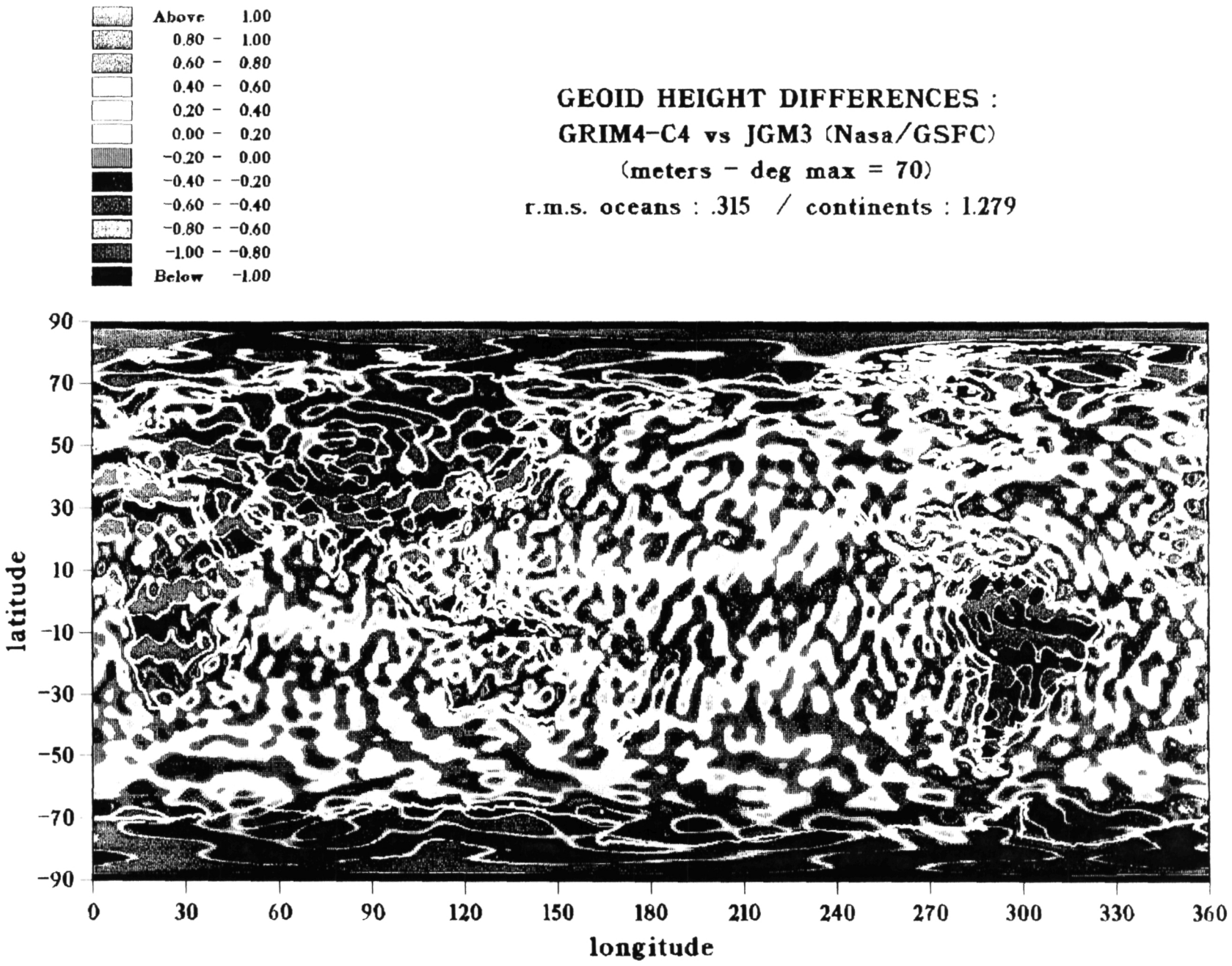
- Gravity Field coefficients
- $C_{2,0}$ secular drift
- Tides (long wavelengths)
- Station Coordinates
- Velocities of 14 Laser stations

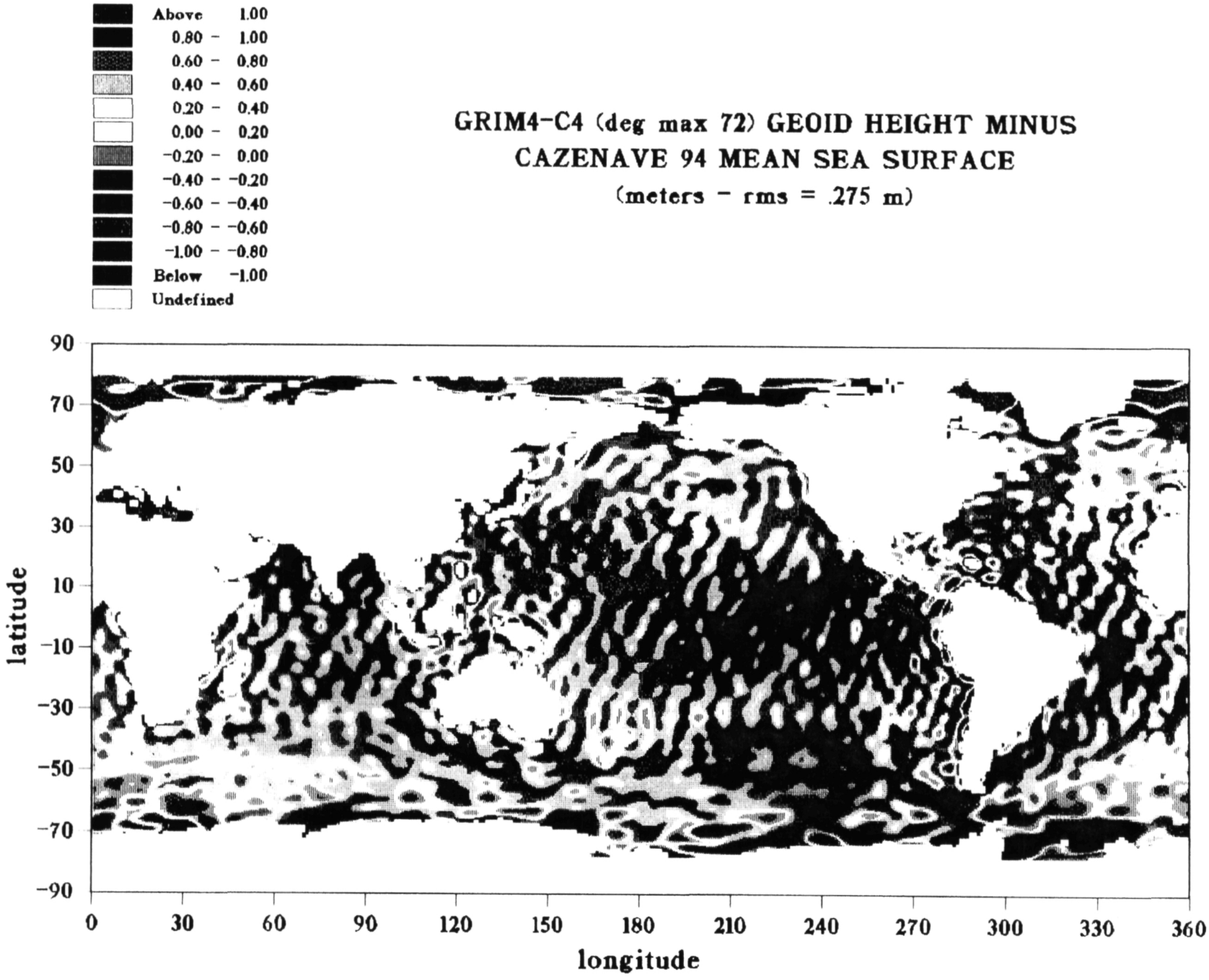
NEW DATA:

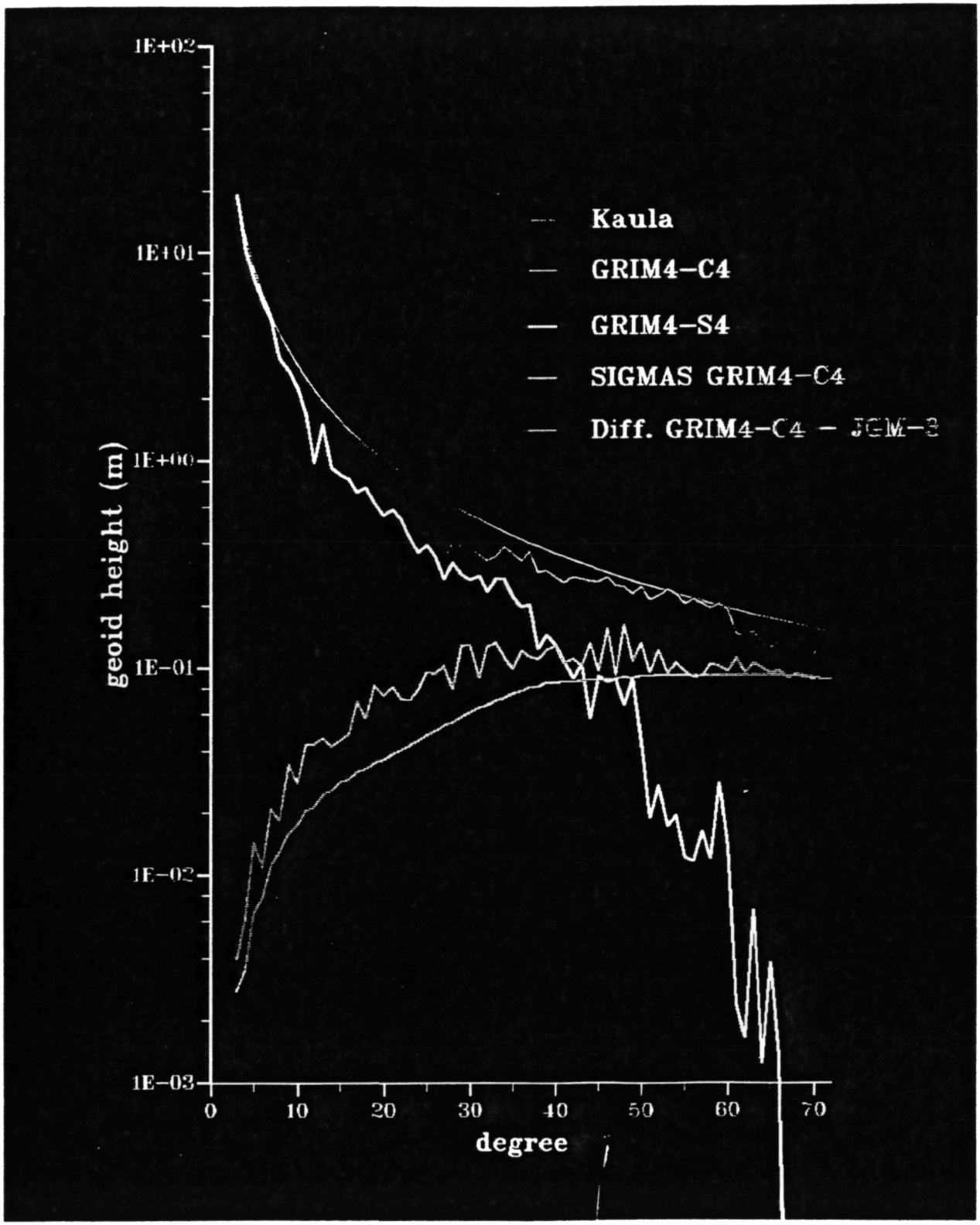
- TOPEX / ERS-1
- LAGEOS-2
- METEOR-3
- STELLA
- TOPEX - GPS
- Surface data (GREENLAND)

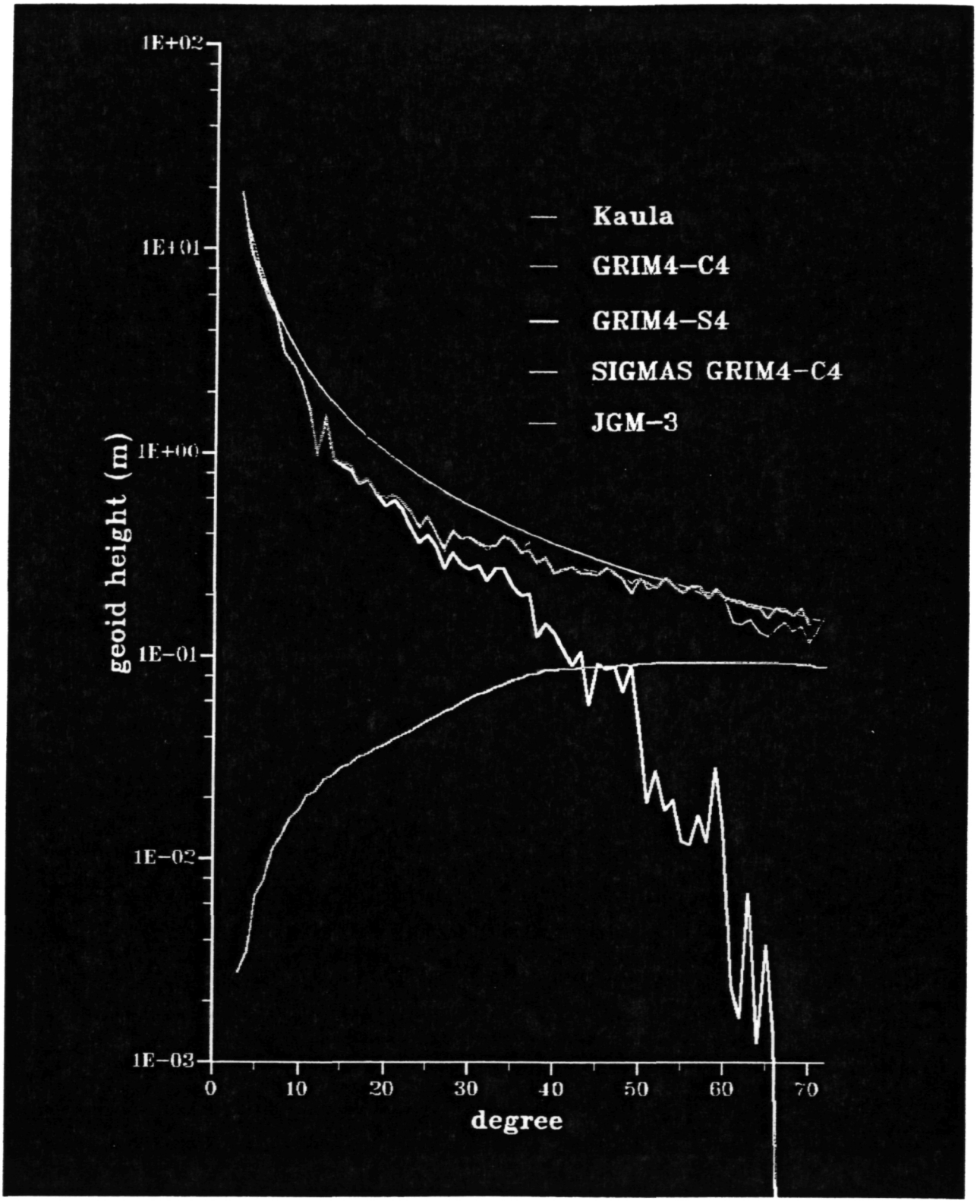
Characteristics of satellites included in the GRIM4 models

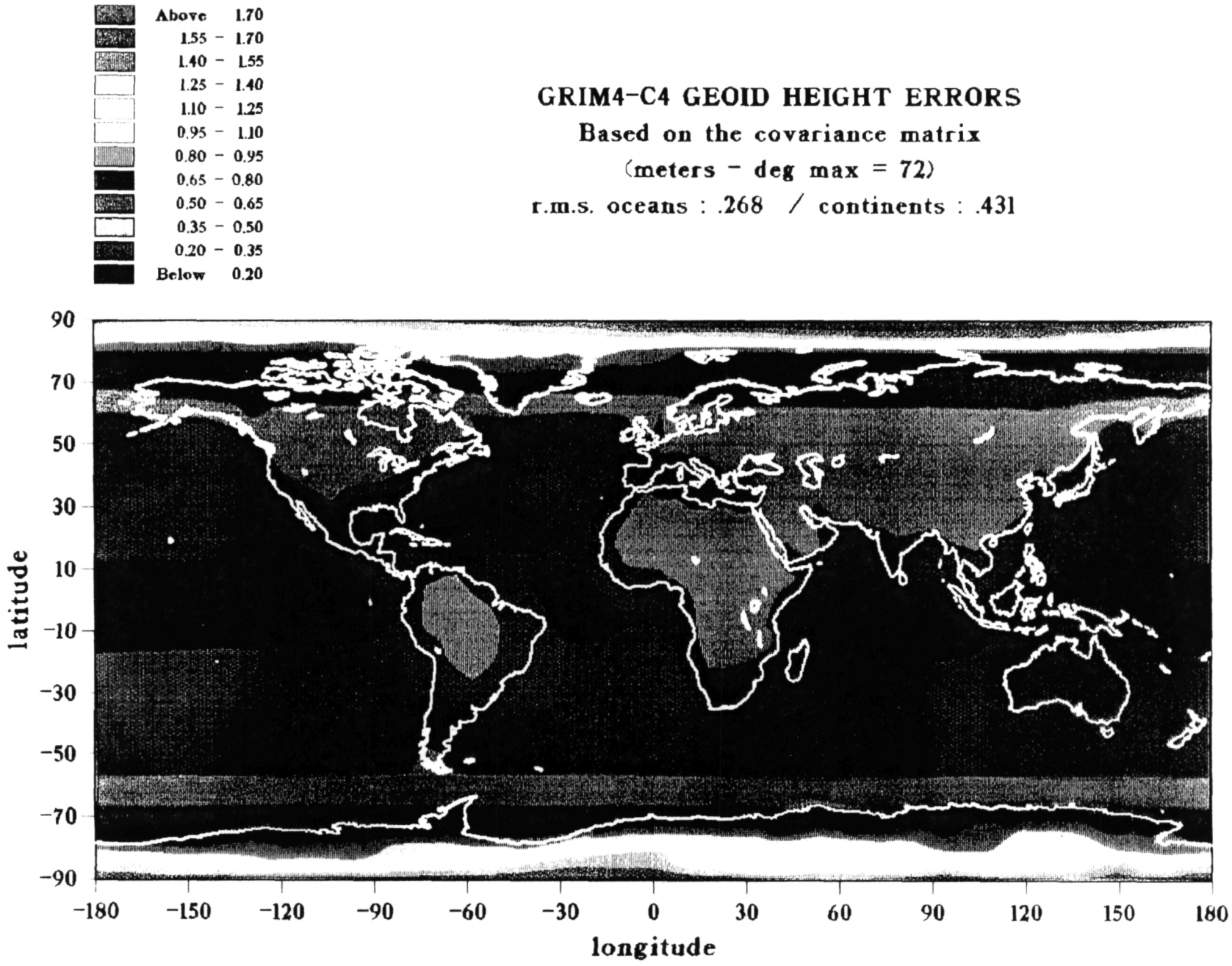
Satellites	A (km)	E	I (°)	Resonance period (d)	Number of Arcs	Type of Observation O	L	MW	Observ. period (Y-1900)
EXPLORER-9	7960.	.108	38.8	9.0	10	10	-	-	62
TRANSIT-4A	7300.	.008	66.8	3.5	8	8	-	-	62
TELSTAR-1	9669.	.243	44.8	14.9	12	12	-	-	62-64
AGENA	7295.	.001	69.9	5.0	3	3	-	-	64
MIDAS-4	9995.	.011	95.8	3.0	48	48	-	-	64-65
BEACON-B	7354.	.014	79.7	3.0	21	20	7	-	64-71
ECHO-1RB	7966.	.012	47.2	11.9	6	6	-	-	65
EXPLORER-19	7800.	.100	78.7	2.0	27	27	-	-	65
VANGUARD-2	8298.	.164	32.9	2.7	10	10	-	-	66
ANNA-1B	7501.	.008	50.1	4.8	16	16	-	-	66
OGO-2	7341.	.075	87.4	3.6	11	11	-	-	66
COURIER-1B	7469.	.016	28.3	3.8	11	11	-	-	66-67
D1-D	7622.	.085	39.5	8.4	11	11	8	-	67/71
D1-C	7341.	.053	40.0	2.5	13	13	9	-	67/71
PEOLE	7006.	.016	15.0	2.1	5	5	5	-	71
GEOS-3	7226.	.001	114.9	4.5	25	-	25	-	75-77
GEOS-2	7711.	.033	105.8	5.7	54	-	54	-	75-77
(ATS6)-GEOS-3	7226.	.001	114.9	4.5		-	-	1	75-78
GEOS-1	8075.	.072	59.4	7.0	39	-	39	-	77-78
BEACON-C	7507.	.026	41.2	5.6	20	-	20	-	79/83
STARLETTE	7331.	.020	49.8	2.8	122	-	122	-	83-84,86-88
LAGEOS	12773.	.004	109.8	2.7	52	-	52	-	83-87
OSCAR-19	7460.	.018	90.2	2.5	18	-	-	18	84
NOVA-1	7557.	.001	90.0	5.5	16	-	-	16	84
AJISAI	7869.	.001	50.0	3.6	70	-	70	-	86-88
GEOSAT	7163.	.001	108.0	2.9	23	-	-	23	86/87
NOVA-3	7571.	.003	90.0	6.2	55	-	-	55	87
ETALON-1	26400.	.001	65.0	7.9	13	-	13	-	89/90
SPOT-2	7200.	.001	98.7	6.2	23	-	-	23	91
LAGEOS 2	12278.	.076	52.0	2.8	8	-	8	-	92-94
TOPEX	7714.	.000	66.0	3.3	7	-	7	7	92
TOPEX/GPS					5	-	-	5	93
ERS1/TOPEX	7160.	.001	98.5	3.0	5	-	5	5	93
STELLA	7178.	.001	98.7	4.0	15	-	15	-	93
METEOR-3	7573.	.002	82.6	10.0	12	-	12	-	94
$n_{sat.}$ = 34						211	451	153	


Above 1.00
0.80 - 1.00
0.60 - 0.80
0.40 - 0.60
0.20 - 0.40
0.00 - 0.20
-0.20 - 0.00
-0.40 - -0.20
-0.60 - -0.40
-0.80 - -0.60
-1.00 - -0.80
Below -1.00
GEOID HEIGHT DIFFERENCES :
GRIM4-C4 vs JGM3 (Nasa/GSFC)
(meters - deg max = 70)
r.m.s. oceans : .315 / continents : 1.279
90
70
50
30
10
-10
-30
-50
-70
-90
latitude
0
30
60
90
120
150
180
210
240
270
300
330
360
longitude


Above 1.00
0.80 - 1.00
0.60 - 0.80
0.40 - 0.60
0.20 - 0.40
0.00 - 0.20
-0.20 - 0.00
-0.40 - -0.20
-0.60 - -0.40
-0.80 - -0.60
-1.00 - -0.80
Below -1.00
Undefined
GRIM4-C4 (deg max 72) GEOID HEIGHT MINUS
CAZENAVE 94 MEAN SEA SURFACE
(meters - rms = .275 m)
90
70
50
30
10
-10
-30
-50
-70
-90
latitude
0
30
60
90
120
150
180
210
240
270
300
330
360
longitude

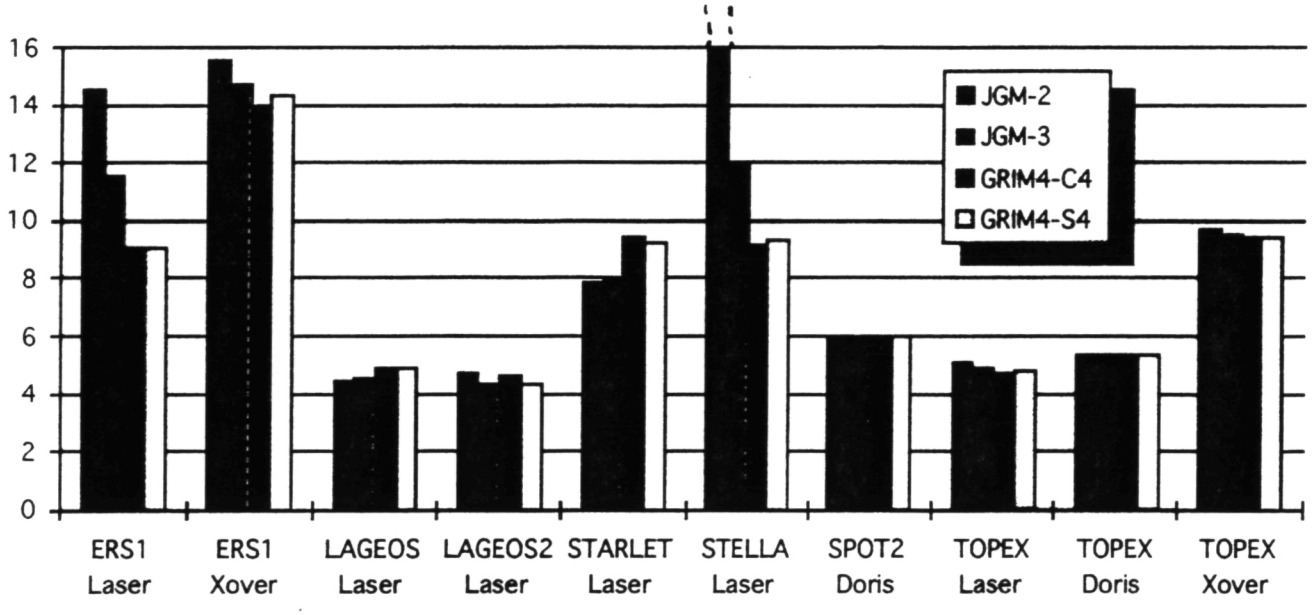

1E+02
1E+01
1E+00
1E-01
1E-02
1E-03
geoid height (m)
0
10
20
30
40
50
60
70
degree
Kaula
GRIM4-C4
GRIM4-S4
SIGMAS GRIM4-C4
Diff. GRIM4-C4 - JGM-3


1E+02
1E+01
1E+00
1E-01
1E-02
1E-03
geoid height (m)
Kaula
GRIM4-C4
GRIM4-S4
SIGMAS GRIM4-C4
JGM-3
0
10
20
30
40
50
60
70
degree


Above 1.70
1.55 - 1.70
1.40 - 1.55
1.25 - 1.40
1.10 - 1.25
0.95 - 1.10
0.80 - 0.95
0.65 - 0.80
0.50 - 0.65
0.35 - 0.50
0.20 - 0.35
Below 0.20
GRIM4-C4 GEOID HEIGHT ERRORS
Based on the covariance matrix
(meters - deg max = 72)
r.m.s. oceans : .268 / continents : .431
90
70
50
30
10
-10
-30
-50
-70
-90
latitude
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
longitude

ORBIT COMPUTATION RESIDUALS WITH DIFFERENT GRAVITY FIELDS

Mean of 3 test arcs for each satellite.
Laser / Xover units: cm
Doris unit: 0.1 mm/s



GRIM4-S4/C4 is available from:

biancale@mfh.cnes.fr

or

lemoine@sc2000.cnes.fr

Space Oceanography Group CLS

SSALT ACCURACY

(BIAS, DRIFT, NOISE)

OZ ZANIFE

- SSALT PRESENTATION
- SSALT MONITORING AND DRIFT
- SSALT ON BOARD MODIFICATIONS
  - PAST AND PRESENT
  - FUTURE

CONTRIBUTORS :

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CLS : P. GASPAR, PY LETRAON, MC DEMMOU, F. OGOR

SWT / 4-12/12/94

Space Oceanography Group CLS

SSALT PRESENTATION

☞ **EXPERIMENTAL SENSOR**

☞ **FLY ON BOARD TOPEX/POSEIDON FOR VALIDATION OF NEW TECHNOLOGIES**

- LOW MASS, LOW POWER
- ON BOARD RETRACKING TO ALLOW LOW TELEMETRY RATE

☞ **IMPORTANT EXPERTISE ACTIVITY**

- TO VALIDATE THE SENSOR
- TO IMPROVE THE ON BOARD SOFTWARES USING IN FLIGHT EXPERIENCE

☞ **PREPARATION OF FUTURE FLIGHTS (TOPEX/POSEIDON FOLLOW ON)**

Space Oceanography Group CLS

SSALT MONITORING AND DRIFT

☞ **SSALT MONITORING PERFORMED BY TWO INTERNAL CALIBRATION MODES**

☞ **CALIBRATION I OR POINT TARGET RESPONSE (PTR)**

- MEASUREMENT OF THE DELAY INSIDE THE ALTIMETER
  ==> USED TO CORRECT THE RANGE DATA
- MEASUREMENT OF THE TOTAL POWER OF THE PTR
  == > USED IN THE SIGMA NAUGHT COMPUTATION

☞ **CALIBRATION II OR LOW PASS FILTERS**

- USED TO COMPUTE OFF NADIR ANGLE
- USED TO CORRECT PTR
- USED TO COMPUTE LOOK UP TABLE

☞ **3 CALIBRATION SEQUENCES (CAL I THEN CAL II) PER DAY WHEN SSALT ON**

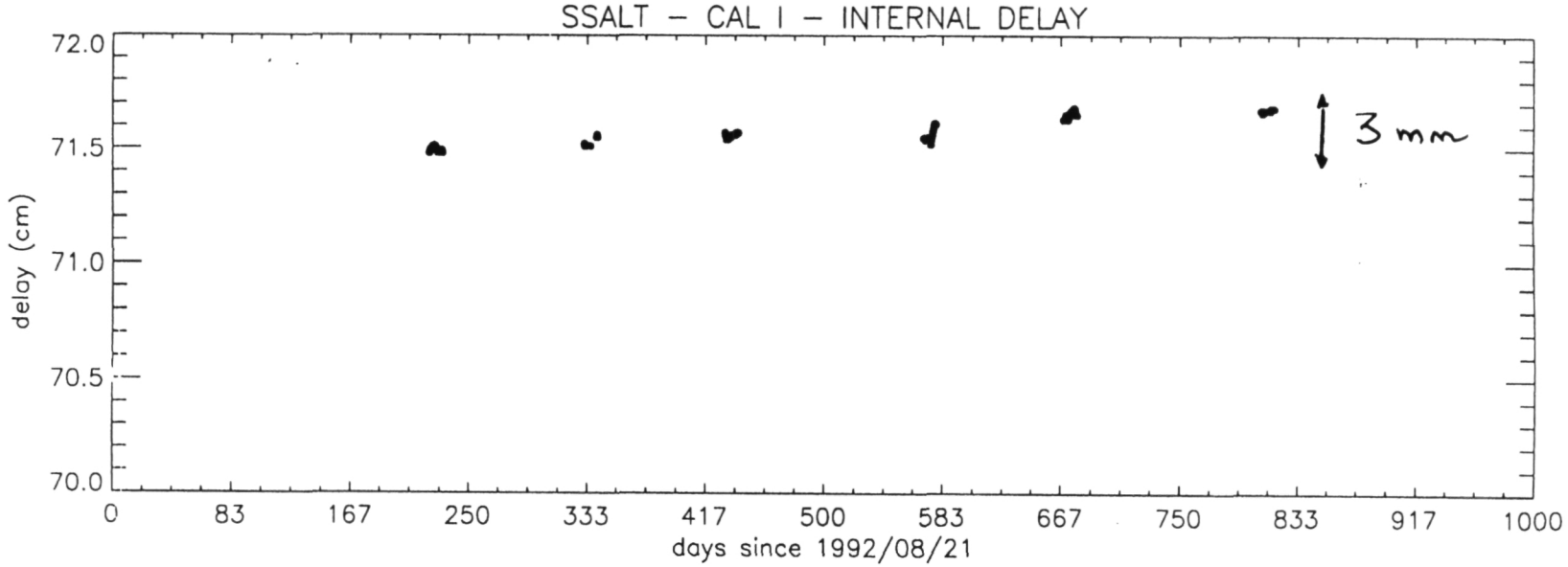
☞ **AUTOMATIC PROCESSING OF THE CALIBRATION DATA**

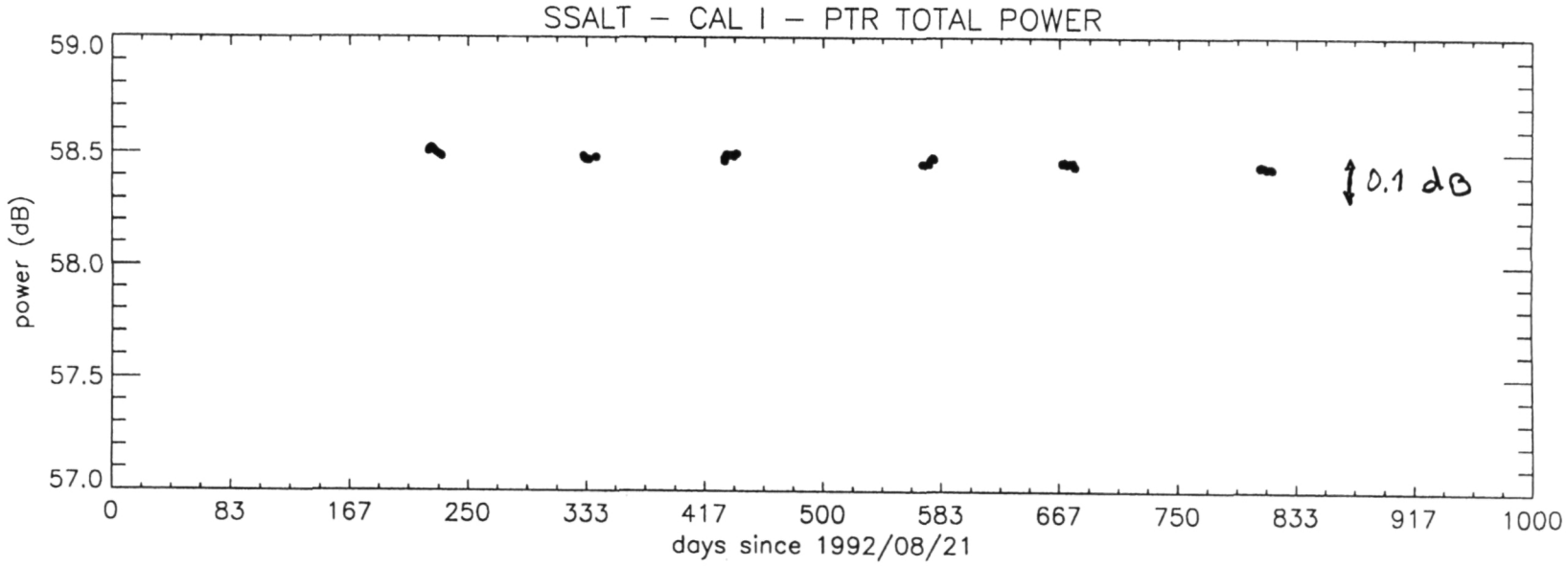
- TO DETECT AND MONITOR ANY DRIFT
- TO CORRECT GDR DATA

☞ **RESULTS AFTER 2 YEARS OF MISSION**

- INTERNAL DELAY : VARIATION OF 3 MM OVER 2 YEARS PERIOD
- TOTAL POWER : VARIATION OF 0.1 DB OVER 2 YEARS PERIOD

GDR ARE CORRECTED FOR DRIFT


SSALT – CAL I – INTERNAL DELAY
72.0
71.5
71.0
70.5
70.0
delay (cm)
3 mm
0
83
167
250
333
417
500
583
667
750
833
917
1000
days since 1992/08/21


SSALT – CAL I – PTR TOTAL POWER
59.0
58.5
58.0
57.5
57.0
power (dB)
0.1 dB
0
83
167
250
333
417
500
583
667
750
833
917
1000
days since 1992/08/21

Space Oceanography Group CLS

PAST AND PRESENT SSALT ON BOARD MODIFICATIONS

(1/2)

☞ **TO IMPROVE NOISE LEVEL OF SSALT**

☞ **USE OF SPECTRAL ANALYSIS WITH 20 HZ DATA TO COMPUTE NOISE LEVEL**

☞ **ON BOARD SOFTWARES :**

- TRACKER ITSELF : - FIRST ORDER LOOP FOR AGC
  - SECOND ORDER LOOP FOR RANGE
- RETRACKING : SIMPLIFIED (QUANTIFIED) VERSION OF MAXIMUM LIKELIHOOD ESTIMATION (MLE)

☞ **MODIFICATIONS HAVE BEEN DONE ON THE COEFFICIENTS USED BY THE TRACKER AND RETRACKING SOFTWARES**

☞ **EVALUATION OF MODIFICATIONS PERFORMED ON THE GROUND USING :**

- DATA FROM SSALT SIMULATOR
- ACTUAL DATA FROM GROUND RETRACKING

Space Oceanography Group CLS

PAST AND PRESENT SSALT ON BOARD MODIFICATIONS

(2/2)

☞ **DESCRIPTION OF MODIFICATIONS**

- SINCE CYCLE 41 ➡ CHANGE OF ON BOARD TRACKER GAINS
- SINCE CYCLE 55 ➡ CHANGE OF ON BOARD RETRACKING GAINS

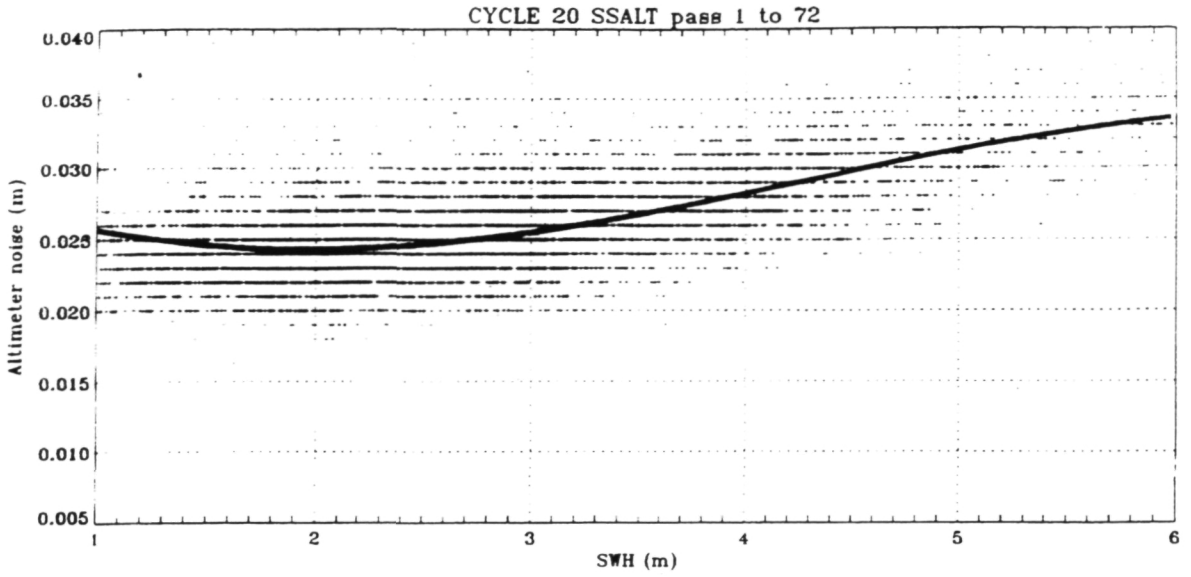
☞ **THESE MODIFICATIONS MOSTLY IMPACT THE NOISE LEVEL OF THE RANGE**

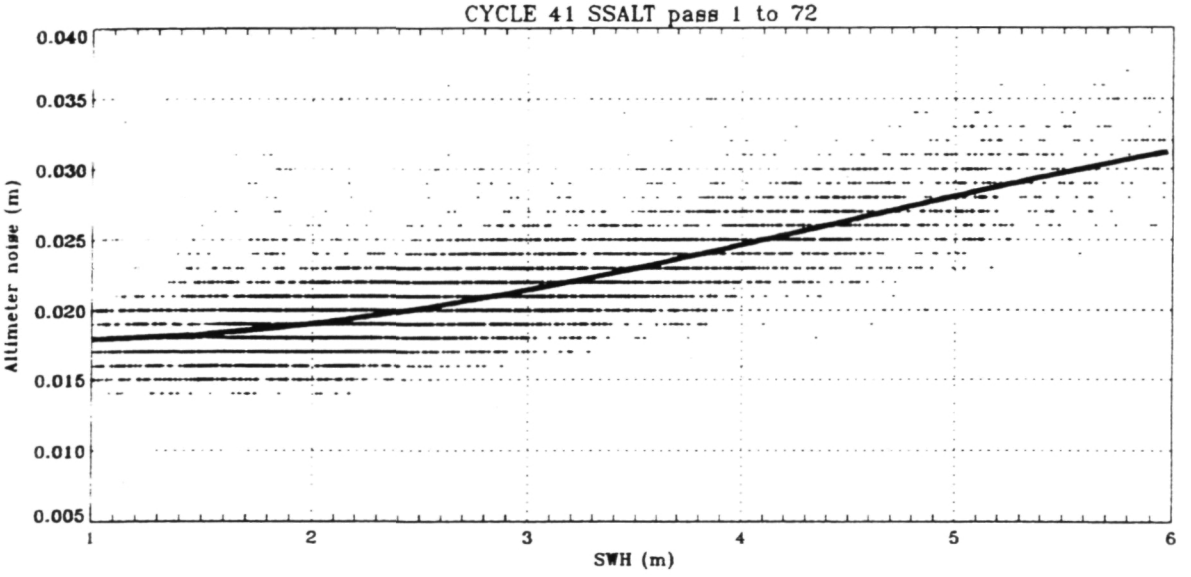
☞ **BEFORE MODIFICATIONS (GDR CYCLE 20, MARCH-APRIL 1993)**

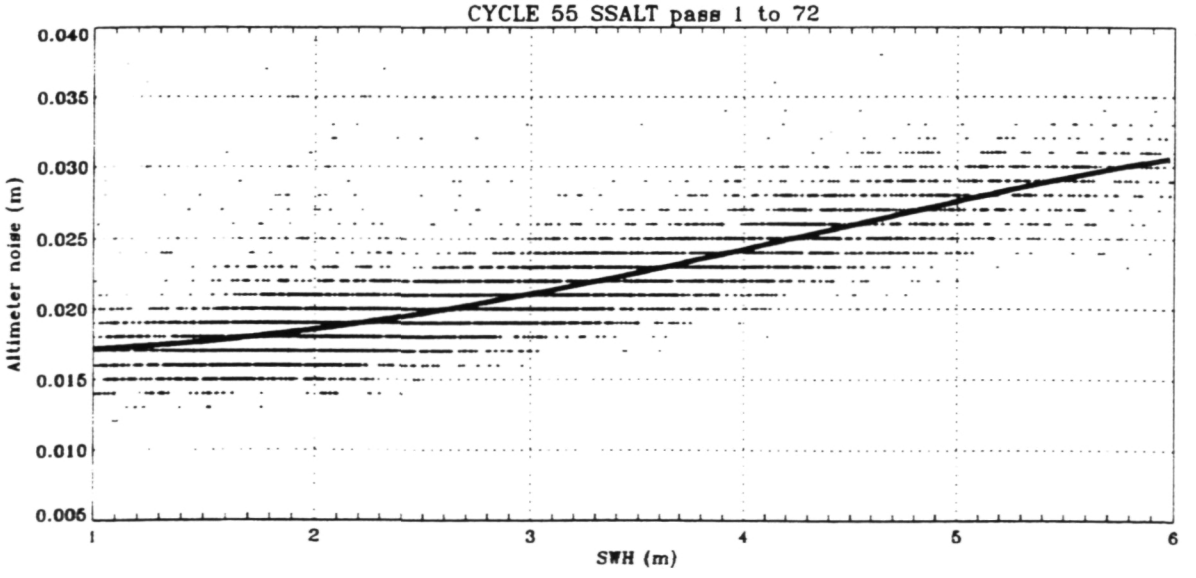
- NOISE LEVEL ABOUT 2.4 CM FOR 2 M SWH

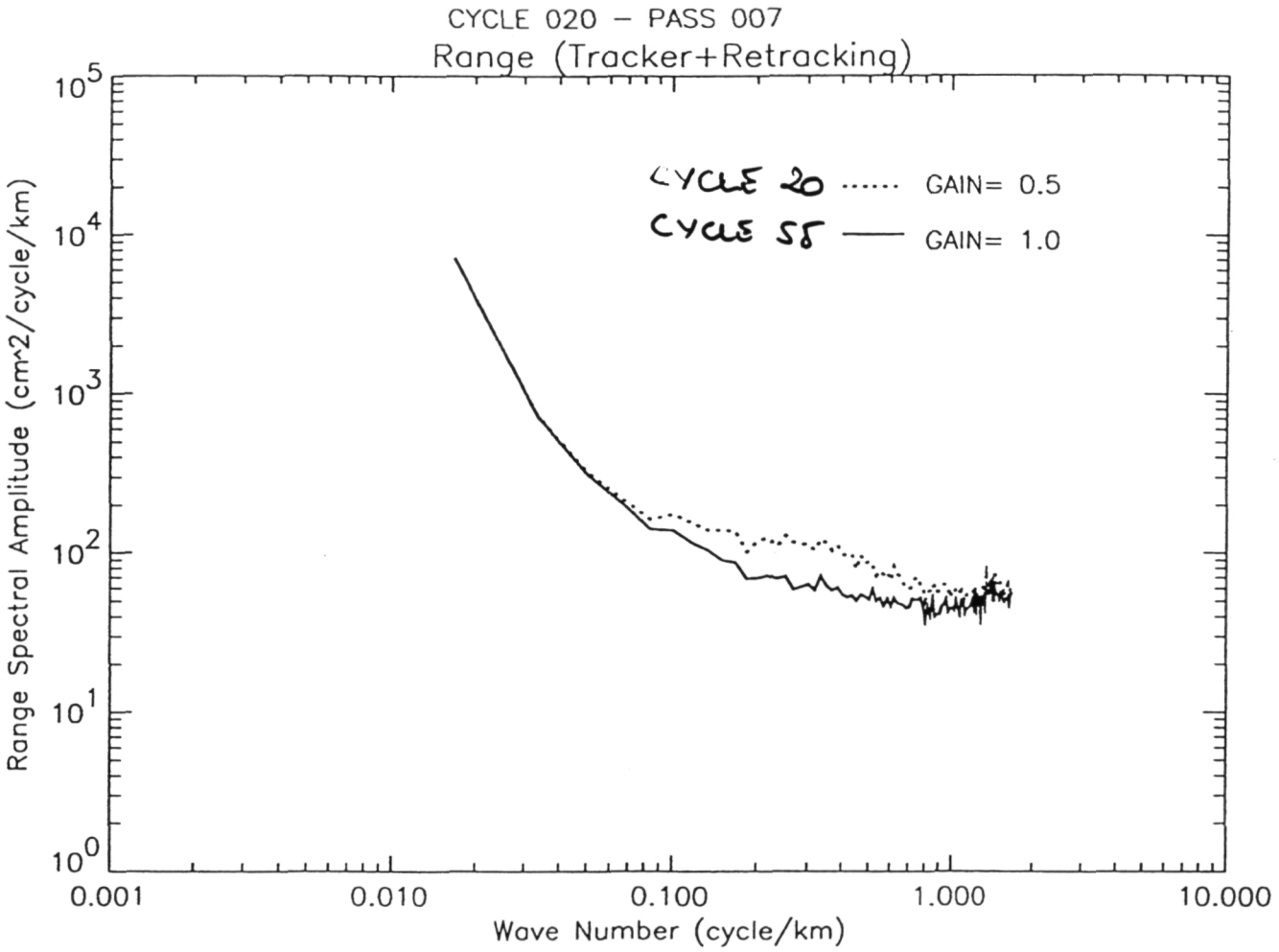
☞ **AFTER MODIFICATIONS (GDR CYCLE 55, MARCH 1994)**

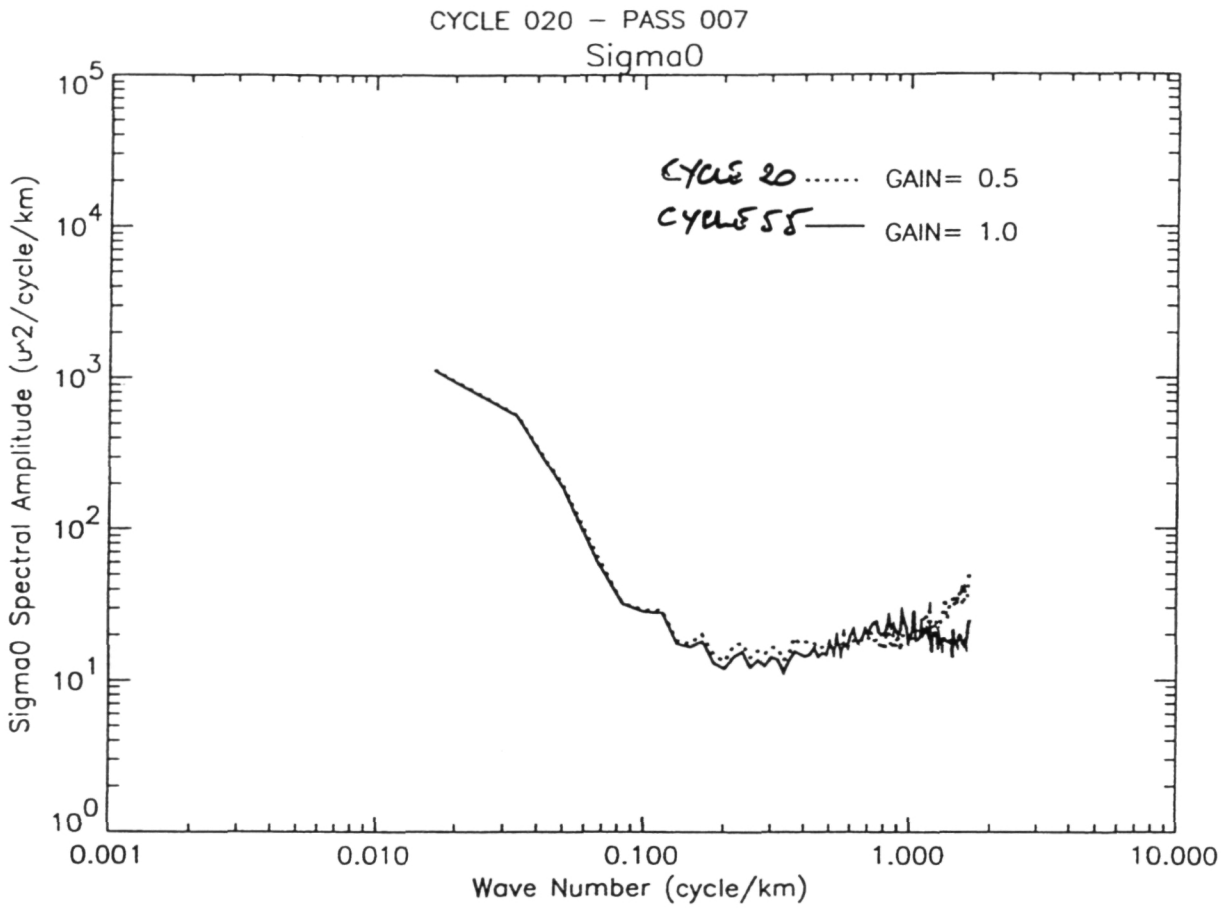
- NOISE LEVEL ABOUT 1.85 CM FOR 2 M SWH
- REMOVAL OF HIGH FREQUENCY ARTIFICIAL FEATURES
- REMOVAL OF QUANTIFICATION EFFECT IN SIGMA NAUGHT DATA

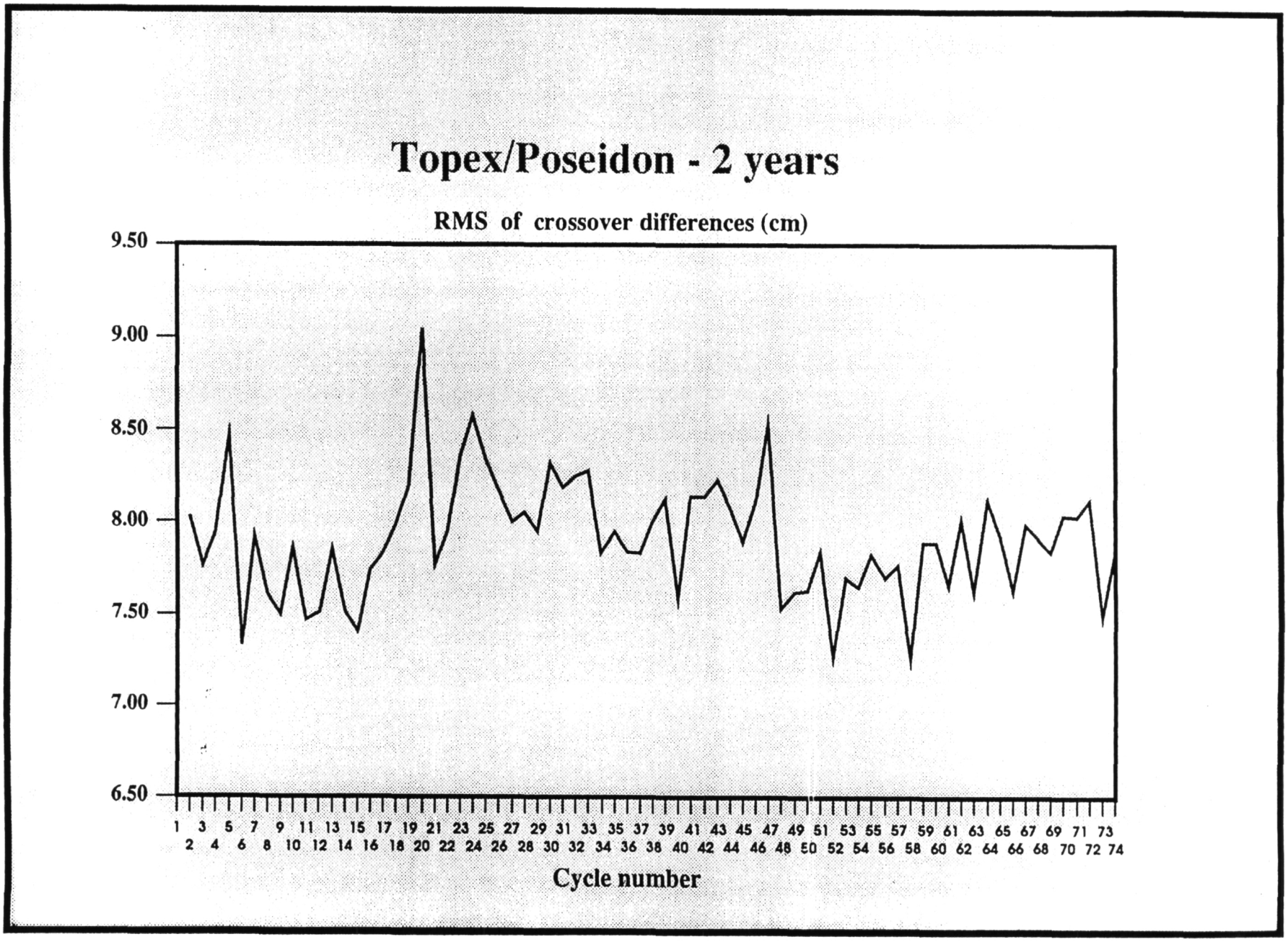

CYCLE 20 SSALT pass 1 to 72
Altimeter noise (m)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
1
2
3
4
5
6
SWH (m)


CYCLE 41 SSALT pass 1 to 72
Altimeter noise (m)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
1
2
3
4
5
6
SWH (m)


CYCLE 55 SSALT pass 1 to 72
Altimeter noise (m)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
1
2
3
4
5
6
SWH (m)


CYCLE 020 – PASS 007
Range (Tracker+Retracking)
CYCLE 20 ..... GAIN= 0.5
CYCLE 58 —— GAIN= 1.0
Range Spectral Amplitude (cm^2/cycle/km)
10^5
10^4
10^3
10^2
10^1
10^0
0.001
0.010
0.100
1.000
10.000
Wave Number (cycle/km)


CYCLE 020 – PASS 007
Sigma0
CYCLE 20 ..... GAIN= 0.5
CYCLE 55 —— GAIN= 1.0
Sigma0 Spectral Amplitude (u^2/cycle/km)
10^5
10^4
10^3
10^2
10^1
10^0
0.001
0.010
0.100
1.000
10.000
Wave Number (cycle/km)


Topex/Poseidon - 2 years
RMS of crossover differences (cm)
9.50
9.00
8.50
8.00
7.50
7.00
6.50
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74
Cycle number

SSALT ON BOARD EVOLUTIONS SUMMARY

CYCLE	EVOLUTION	IMPACT
20	/	NOISE LEVEL --------> **2.4 CM** EM BIAS COEF. ---> **4.7 % SWH**
41	TRACKER GAINS	NOISE LEVEL --------> **1.9 CM**
55	RETRACKING GAINS	NOISE LEVEL --------> **1.85 CM** HIGH FREQUENCY FEATURE QUANTIFICATION EFFECTS
NEAR FUTURE	TUNING OF ON BOARD TABLES	EM BIAS COEFF. **2.7 % OF SWH**
TPFO	REAL MLE	NOISE LEVEL --------> **1.65 CM**

FUTURE
SSALT ON BOARD MODIFICATIONS

(1/2)

☞ **TO IMPROVE SSALT NOISE LEVEL**
TO UNDERSTAND APPARENT TRACKER BIAS

☞ **CURRENT STATUS AFTER TWO YEARS OF MISSION**

- SSALT NOISE LEVEL OF 1.85 CM FOR 2 M SWH
- SSALT EM BIAS OF ABOUT 4.7 % OF SWH (INCLUDING SKEWNESS EFFECTS)
- TOPEX EM BIAS IS ABOUT 2 % OF SWH (INCLUDING 0.4% OF SWH SKEWNESS EFFECTS CORRECTED SEPARETELY)

☞ **DESCRIPTION OF MODIFICATIONS NOT YET IMPLEMENTED BUT ALREADY TESTED**

- FOCUS ON RETRACKING ALGORITHM
- DEVELOPMENT OF A **"REAL"** VERSION MLE SOFTWARE (WITHOUT ANY QUANTIFICATION)
- IMPROVEMENT OF THE ON BOARD **"QUANTIFIED"** VERSION THROUGH THE FINE TUNING OF THE DERIVATIVE TABLES ON BOARD SSALT

☞ **RETRACKING OF WAVEFORMS BY BOTH SOFTWARE VERSIONS HAVE BEEN PERFORMED**

☞ **NEW TABLES HAVE BEEN SUCCESFULLY LOADED AND TESTED AT THE END OF CYCLE 79 (NOVEMBER 15, 1994)**

ORIGINAL PAGE IS
OF POOR QUALITY

FUTURE
SSALT ON BOARD MODIFICATIONS

(2/2)

☞ **RESULTS**

• NOISE LEVEL

- NEW QUANTIFIED VERSION : VERY SMALL CHANGE COMPARE TO CYCLE 55
- REAL VERSION OF MLE : NOISE LEVEL ABOUT **1.65 CM**

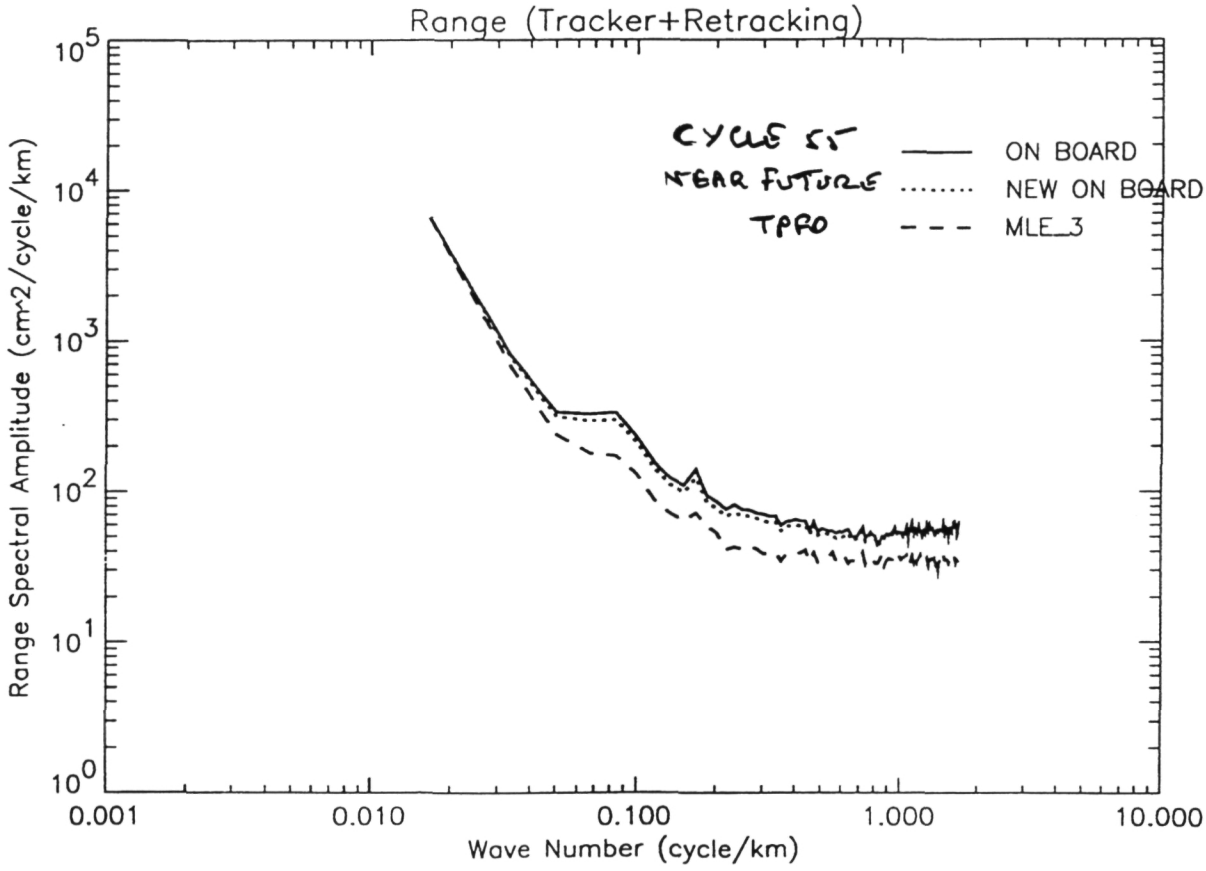
• EM BIAS COEFFICIENTS

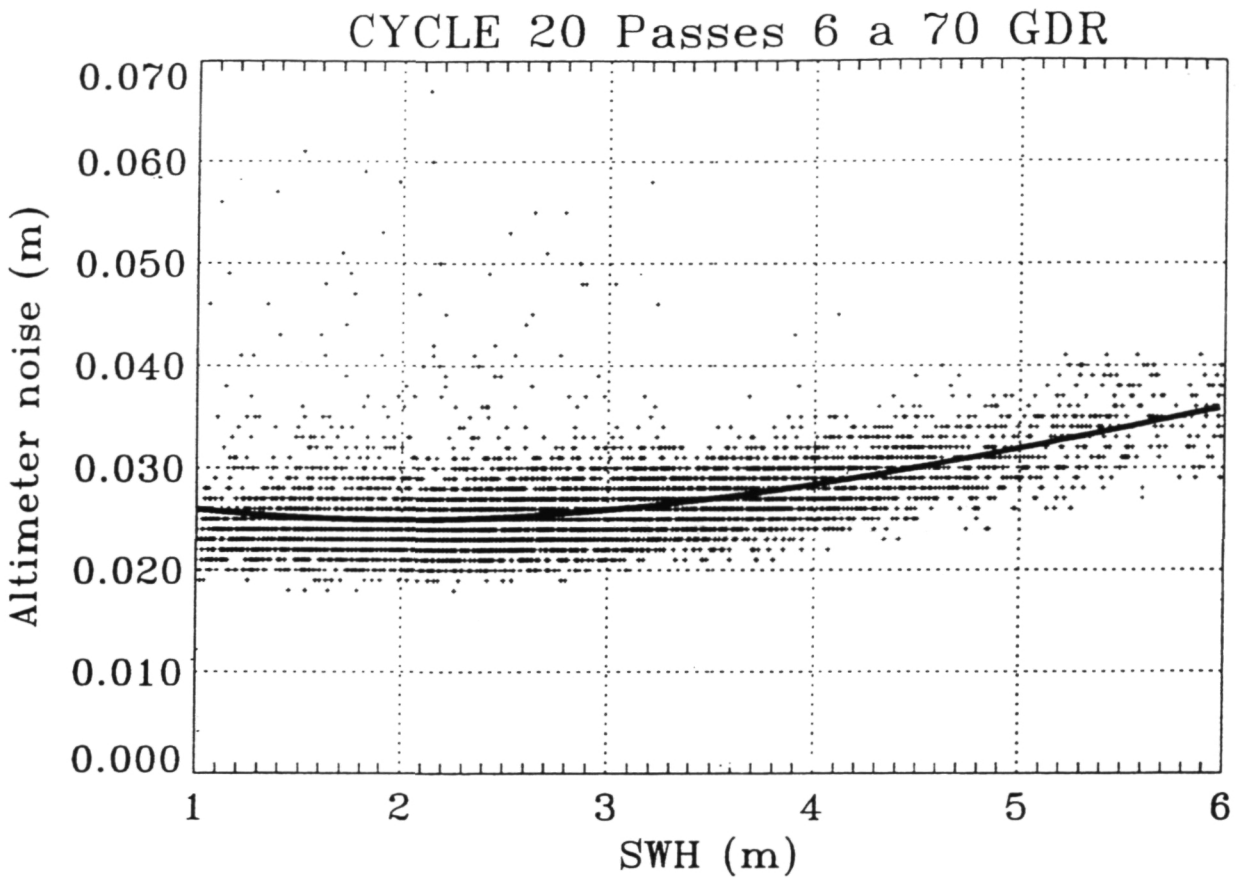
- BOTH VERSIONS AGREE AND SHOW A DECRASE IN THE EM BIAS COEFFICIENT BY ABOUT **1.6 % OF SWH**
- THIS IS ALSO OBSERVED WHEN COMPUTING EM BIAS COEFFICIENT USING CROSSOVER METHOD
- NEW VALUE OF SSALT EM BIAS IS ABOUT **2.7 %** OF SWH (INCLUDE 0.4 % FOR 0.1 SKEWNESS CORRECTION)

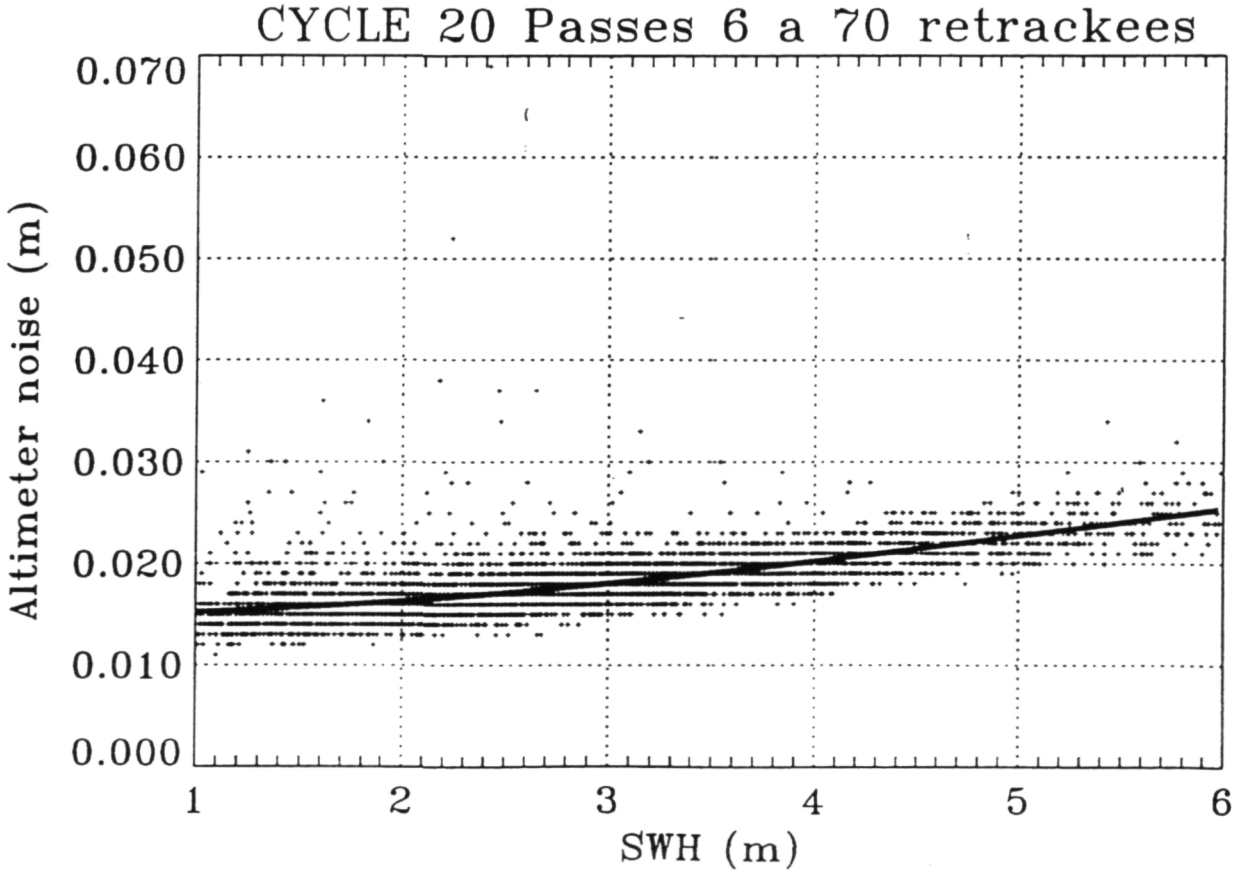
☞ **THE ON BOARD MODIFICATION MOSTLY IMPACTS THE TRACKER BIAS**
SO FAR IT HAS NOT BEEN IMPLEMENTED

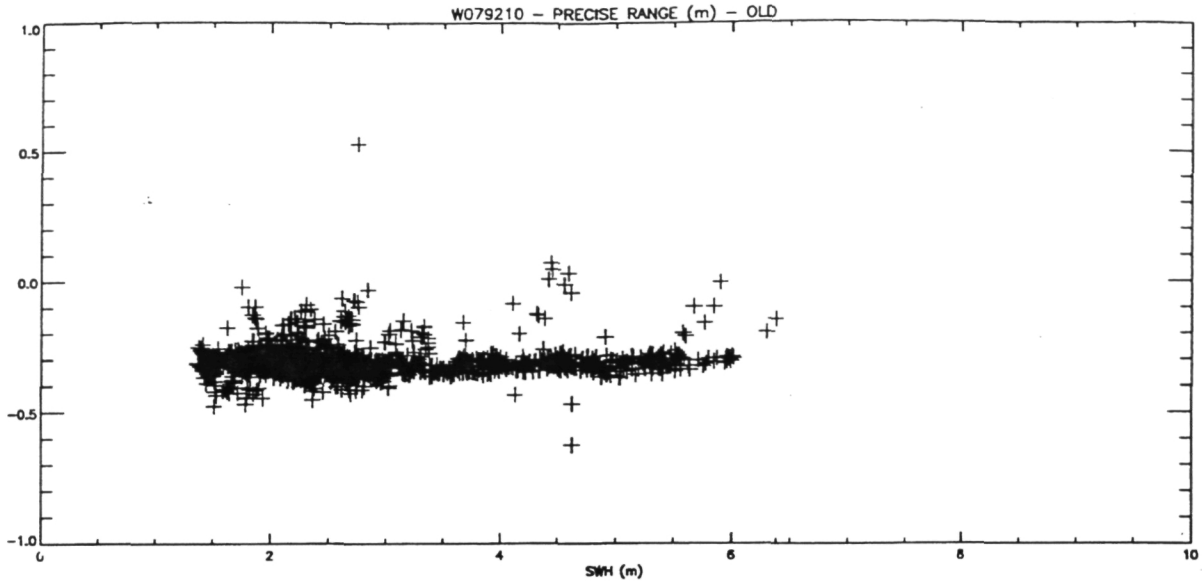
THE USE OF BEM4 (GASPAR AND AL., 1994) IS RECOMMANDED UNTIL THIS MODIFICATION IS IMPLEMENTED

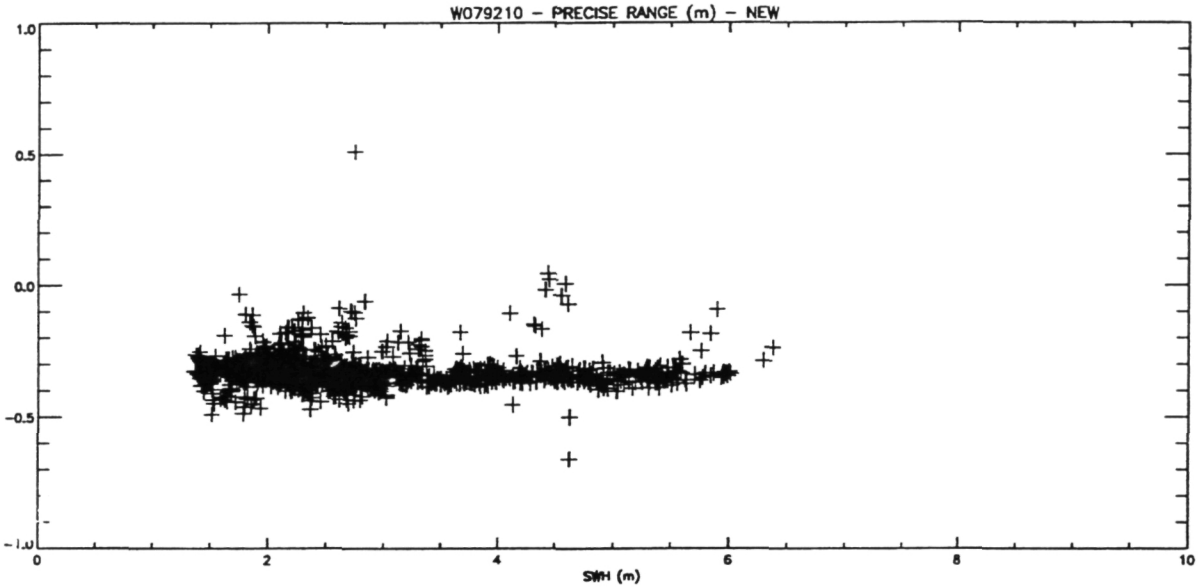
CYCLE 079 – PASS 210

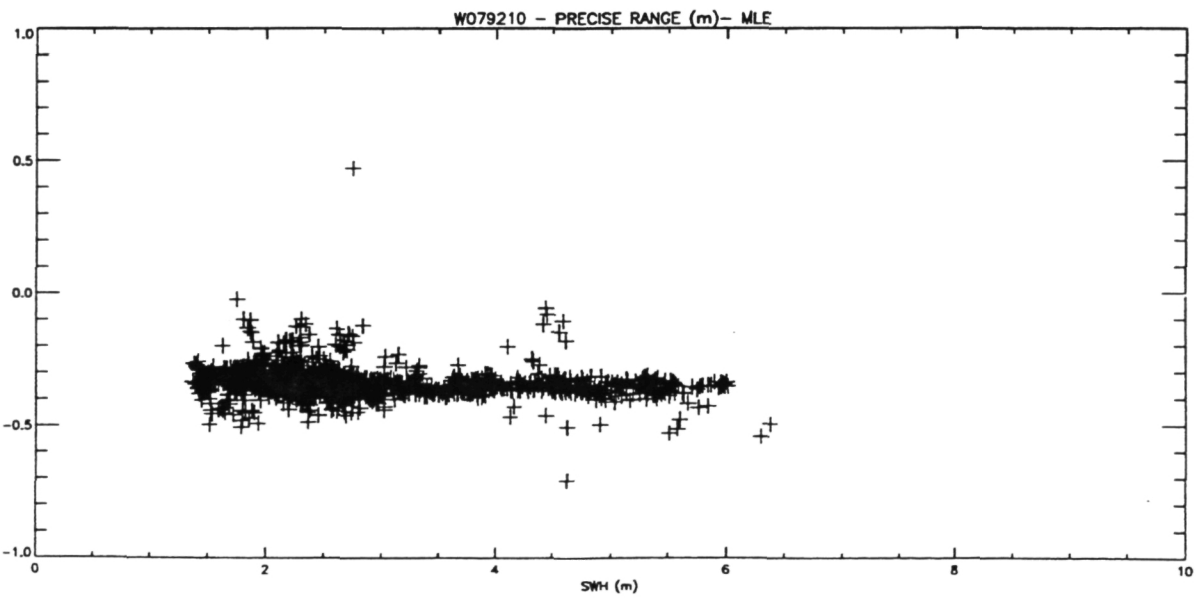


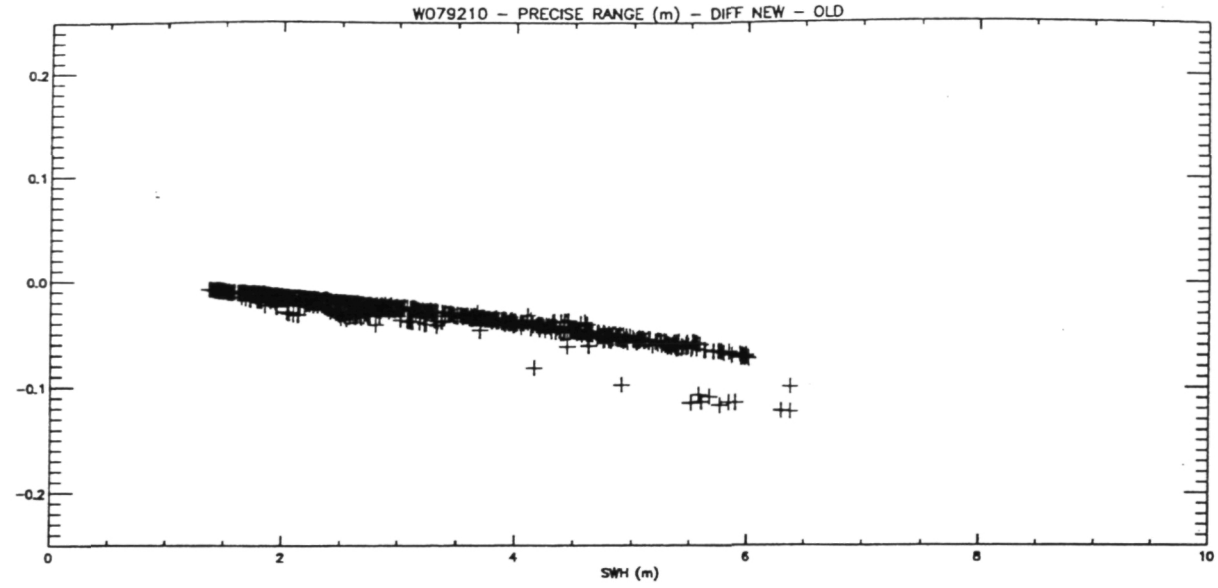

CYCLE 20 Passes 6 a 70 GDR
Altimeter noise (m)
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
1
2
3
4
5
6
SWH (m)

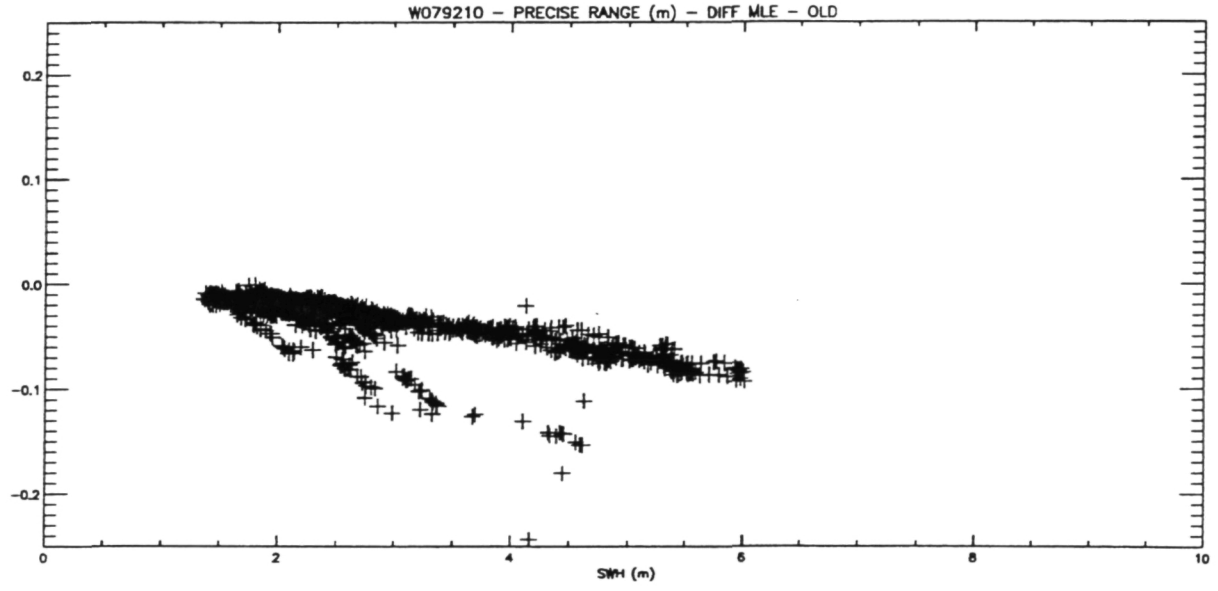

CYCLE 20 Passes 6 a 70 retrackees
Altimeter noise (m)
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
1
2
3
4
5
6
SWH (m)

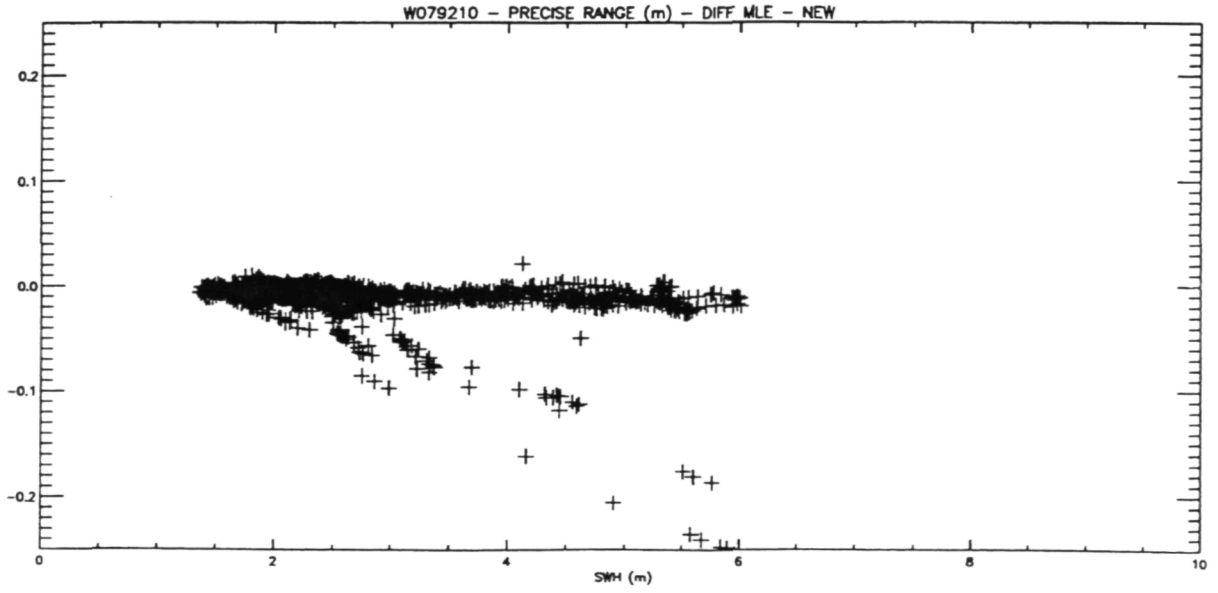

W079210 – PRECISE RANGE (m) – OLD
1.0
0.5
0.0
-0.5
-1.0
0
2
4
6
8
10
SWH (m)


W079210 – PRECISE RANGE (m) – NEW
1.0
0.5
0.0
-0.5
0
2
4
6
8
10
SWH (m)


W079210 – PRECISE RANGE (m)– MLE
1.0
0.5
0.0
-0.5
-1.0
0
2
4
6
8
10
SWH (m)


W079210 – PRECISE RANGE (m) – DIFF NEW – OLD
0.2
0.1
0.0
-0.1
-0.2
0
2
4
6
8
10
SWH (m)


W079210 – PRECISE RANGE (m) – DIFF MLE – OLD
0.2
0.1
0.0
-0.1
-0.2
0
2
4
6
8
10
SWH (m)


W079210 – PRECISE RANGE (m) – DIFF MLE – NEW
0.2
0.1
0.0
-0.1
-0.2
0
2
4
6
8
10
SWH (m)

CONCLUSIONS

☞ SSALT PERFORMANCES ARE WITHIN REQUIREMENTS

☞ VERY SMALL DRIFTS OF THE ALTIMETER HAVE BEEN DETECTED AND DATA ARE CORRECTED THANKS TO INTERNAL CALIBRATION MEASUREMENTS

☞ SSALT NOISE LEVEL HAS BEEN DECREASING SINCE CYCLE 41 AND FURTHER SINCE CYCLE 55

☞ TRACKER BIAS IS BETTER UNDERSTOOD

THE USE OF BEM4 (GASPAR AND AL, 1994) FOR EM BIAS CORRECTION IS STILL RECOMMANDED UNTIL ON BOARD RETRACKING MODIFICATION IS IMPLEMENTED

☞ USE OF AN OFF LINE "REAL" MLE RETRACKING GIVES PROMISING RESULTS

WE STILL HAVE ROOM FOR FURTHER IMPROVEMENTS OF SSALT OPERATIONNEL PRODUCTS

D. Chelton

TOPEX SEA-STATE BIAS

(NASA Altimeter)

- Stewart and Devalla
- Rodríguez and Martin
- Glazman, Greysukh and Srokosz
* - Gaspar, Ogor, LeTraon and Zanife
* - Chelton

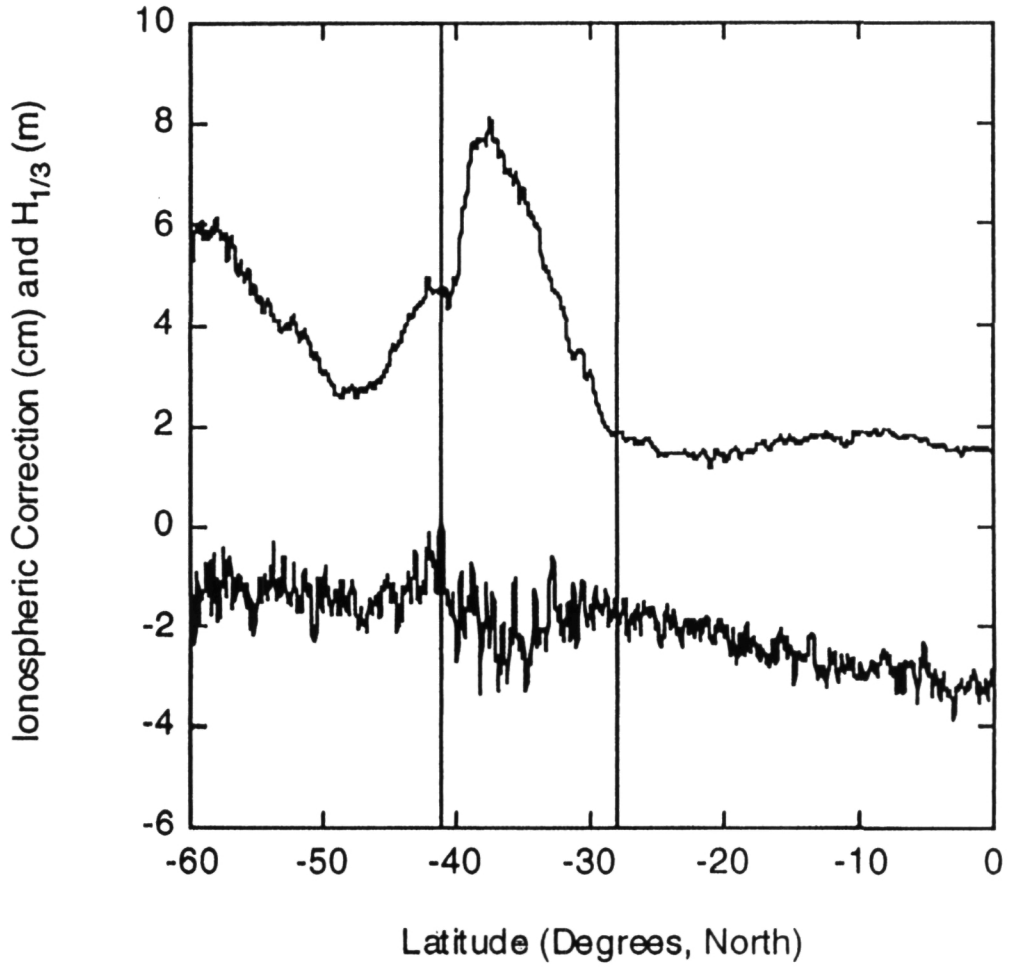


Figure 2. Significant wave height $H1/3$ (top) and ionospheric correction δ_{ion} (bottom) observed by TOPEX/POSEIDON on cycle 38 pass 169 over a south Pacific storm at 38°S & 135°W. Data from 28°S to 42°S were used in Table 1. δ_{ion} was smoothed with a 5-point running mean to reduce noise. Note that both $H1/3$ and short-wavelength ionospheric variability contribute to δ_{ion}.

Rodríguez and Martin (1994): "Estimation of EM bias from retracked TOPEX data."

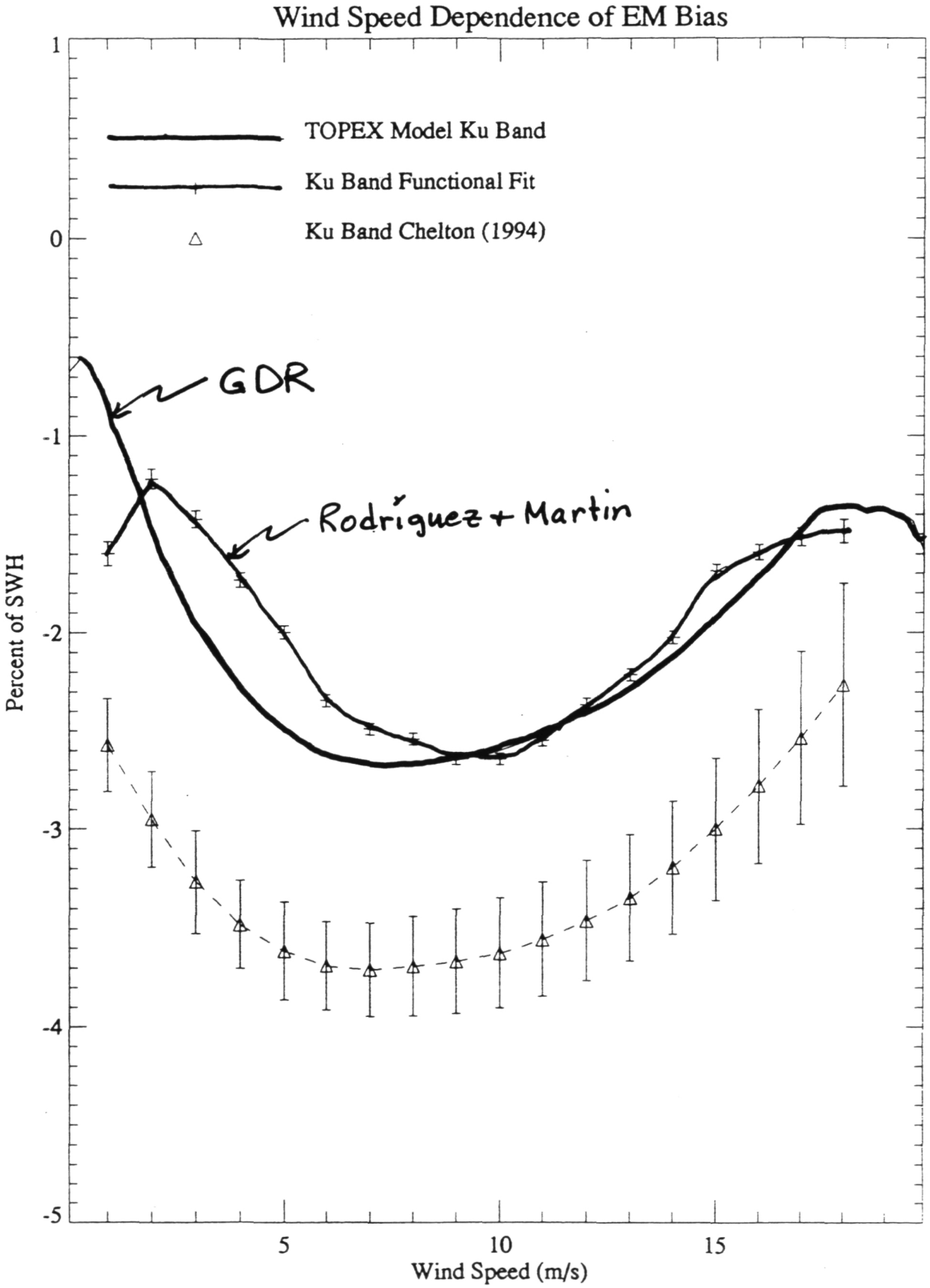
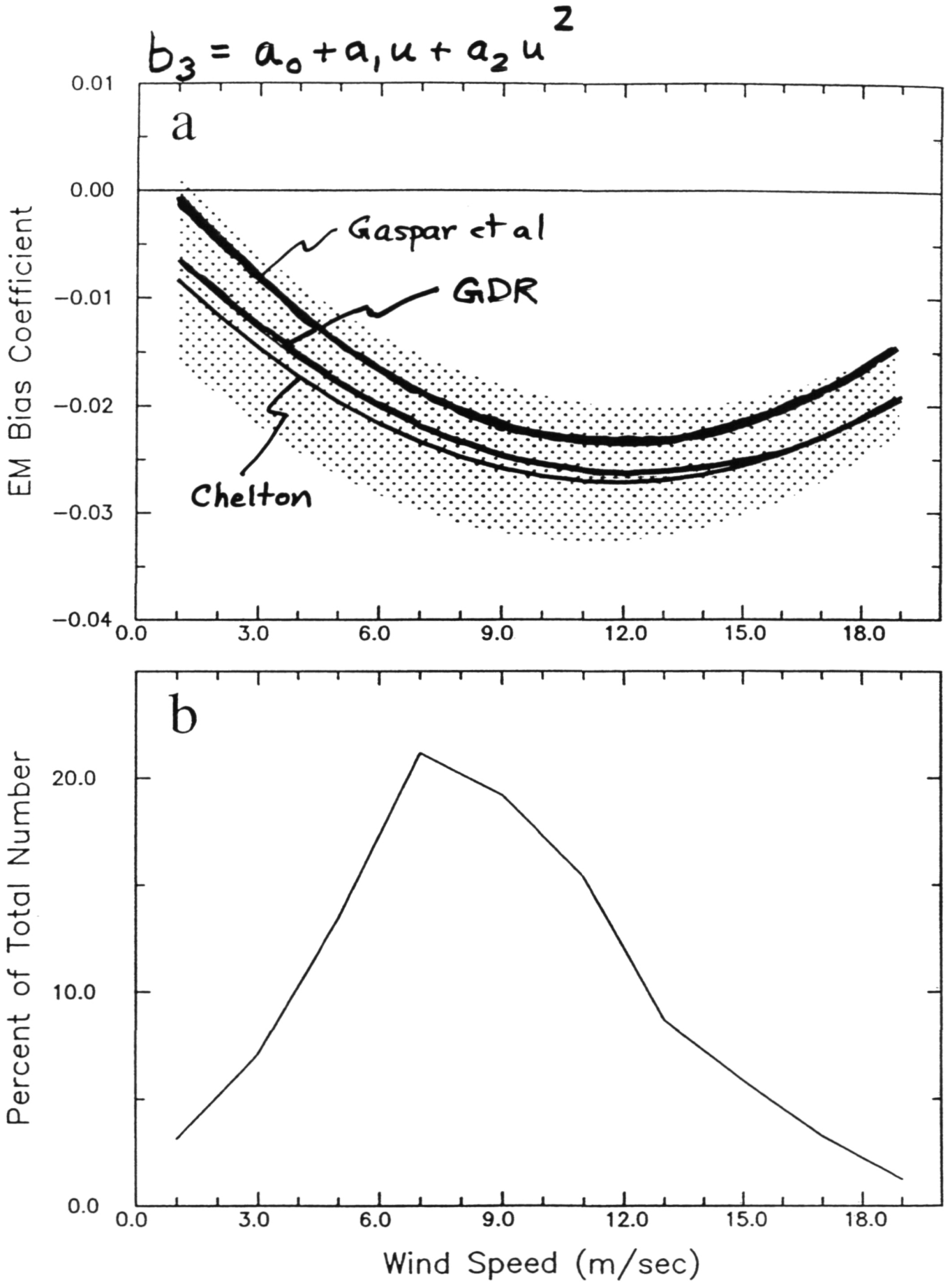


Table 1. The Parameters of the Quadratic Wind Speed Dependent Model $b = a_0 + a_1 u + a_2 u^2$ for the Sea State Bias Coefficient

	GDR	Collinear Regression	Crossover Regression
a_0	-0.0029	-0.0047 ± 0.0086	0.0036 ± 0.007
a_1	-0.0038	-0.0038 ± 0.0007	-0.0045 ± 0.0008
a_2	1.55×10^{-4}	$(1.6 \pm 0.3) \times 10^{-4}$	$(1.9 \pm 0.3) \times 10^{-4}$
VAR	7.67	7.67	7.35

The three values for each parameter correspond to (1) the values used in the GDR processing, (2) the values derived here by regression analysis of collinear TOPEX Data, and (3) the values derived by *Gaspar et al.* [this issue] by regression analysis of crossover difference TOPEX data. The bottom row of the table gives the reduced variance (VAR) of sea level in cm^2 after removal of the sea state bias.


$b_3 = a_0 + a_1 u + a_2 u^2$
a
b
EM Bias Coefficient
Percent of Total Number
Wind Speed (m/sec)
Gaspar et al
GDR
Chelton
0.01
0.00
−0.01
−0.02
−0.03
−0.04
20.0
10.0
0.0
0.0
3.0
6.0
9.0
12.0
15.0
18.0

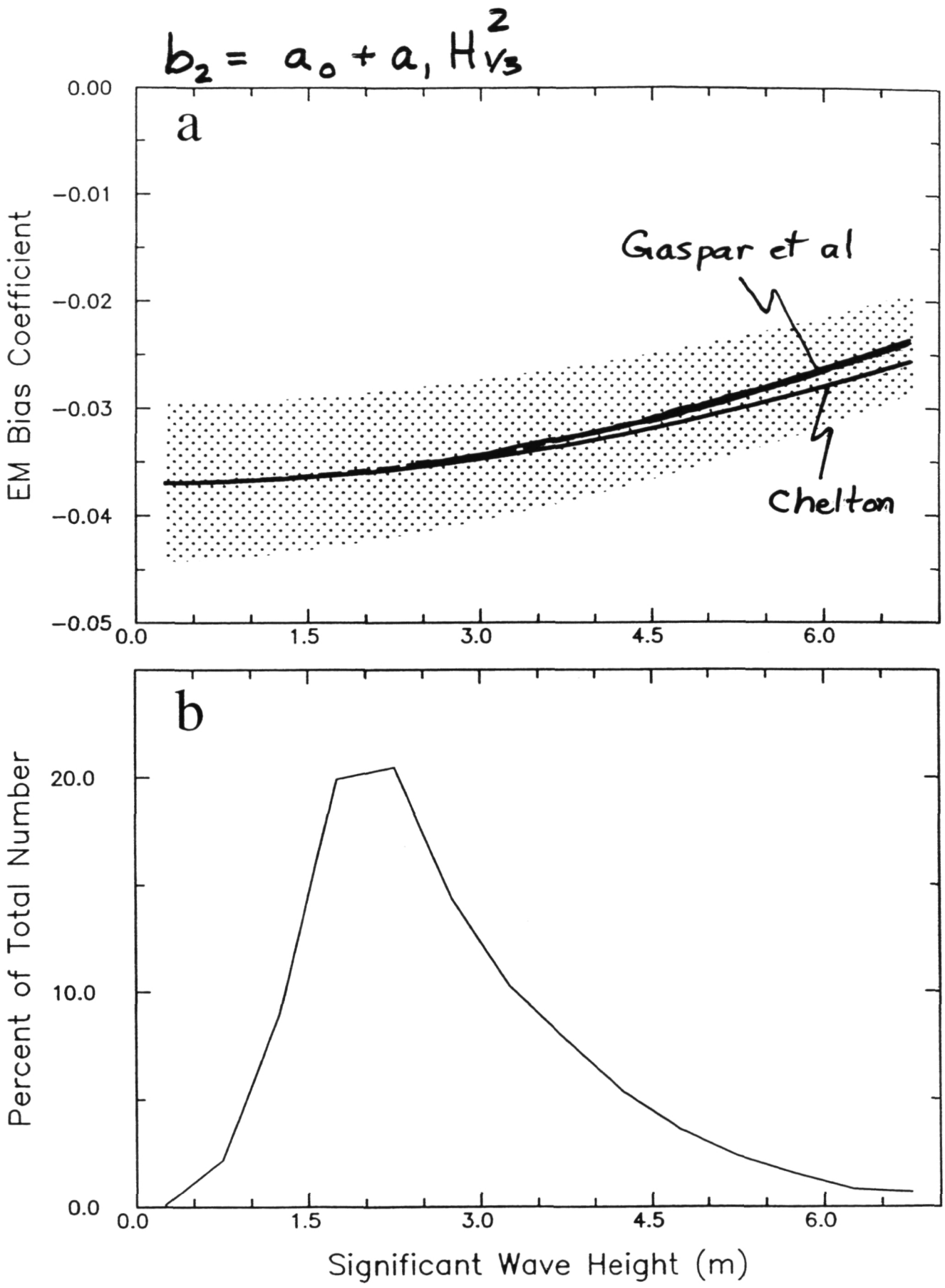

$b_2 = a_0 + a_1 H_{V3}^2$
a
EM Bias Coefficient
0.00
−0.01
−0.02
−0.03
−0.04
−0.05
Gaspar et al
Chelton
0.0
1.5
3.0
4.5
6.0
b
Percent of Total Number
20.0
10.0
0.0
0.0
1.5
3.0
4.5
6.0
Significant Wave Height (m)

Table 3. The Symmetric 4×4 Matrix of Cross Correlations Between Wind Speed (u), Wind Speed Squared, Significant Wave Height ($H_{1/3}$), and Significant Wave Height Squared

Glazman

	u	u^2	$H_{1/3}$	$H_{1/3}^2$	P_{atm}
u	1.00	0.96	0.74	0.68	-0.33
u^2		1.00	0.78	0.75	-0.37
$H_{1/3}$			1.00	0.95	-0.19
$H_{1/3}^2$				1.00	

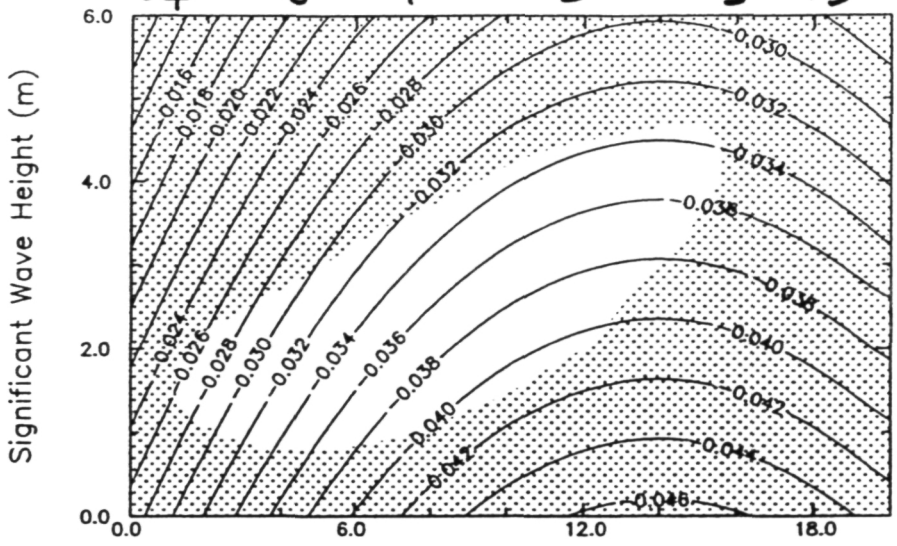
Table 4. The Parameters of the Wind Speed and Wave Height Dependent Model $b = a_0 + a_1 u + a_2 u^2 + a_3 H_{1/3}$ for the Sea State Bias Coefficient

	Collinear Regression	Crossover Regression
a_0	-0.027 ± 0.016	-0.019 ± 0.009
a_1	-0.0028 ± 0.0009	-0.0037 ± 0.0008
a_2	$(1.0 \pm 0.3) \times 10^{-4}$	$(1.4 \pm 0.3) \times 10^{-4}$
a_3	0.0028 ± 0.0012	0.0027 ± 0.0011
VAR	8.04	7.87

The two values for each parameter correspond to (1) the values derived here by regression analysis of collinear TOPEX data and (2) the values derived by *Gaspar et al.* [1994] by regression analysis of crossover difference TOPEX data. The bottom row of the table gives the reduced variance (VAR) of sea level in cm^2 after removal of the sea state bias.

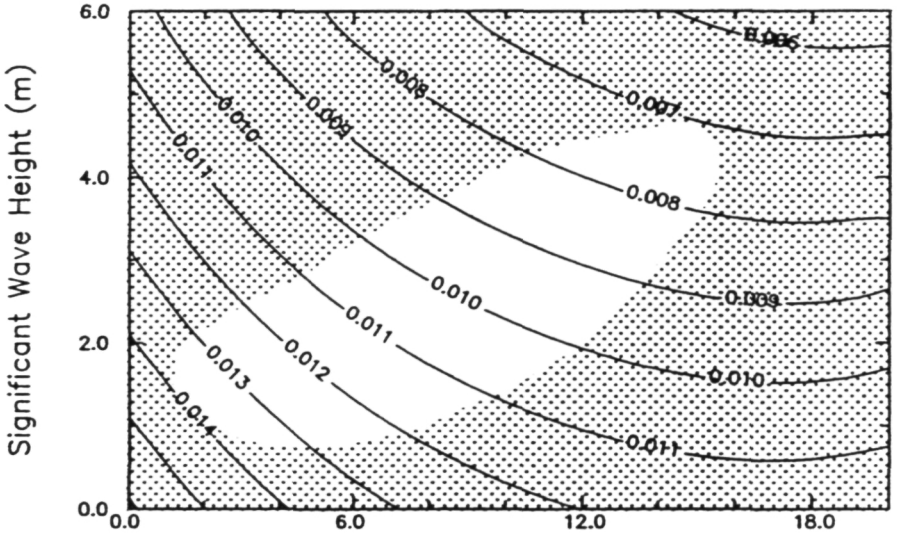
$$b_4 = a_0 + a_1 u + a_2 u^2 + a_3 H_{1/3}$$

a



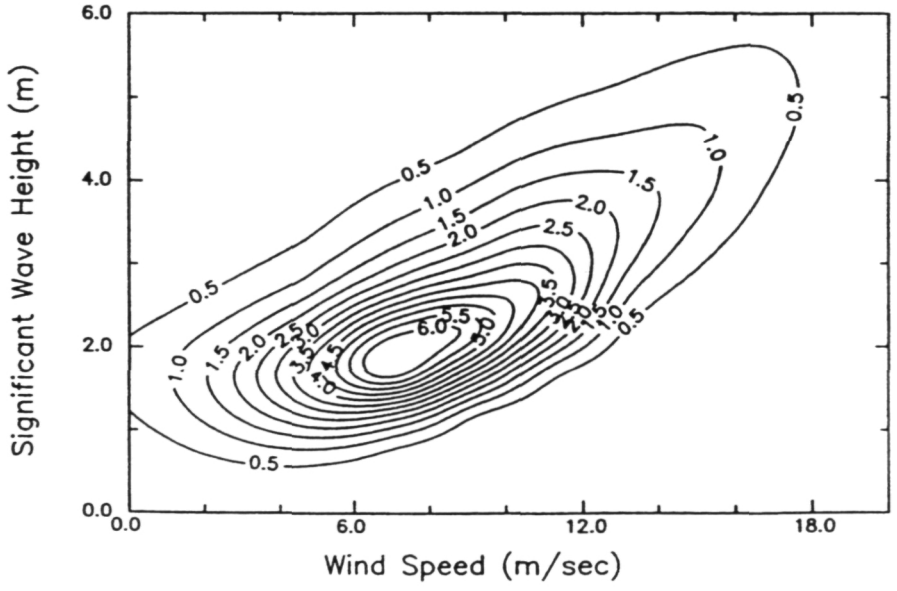
Chelton coefficients

b



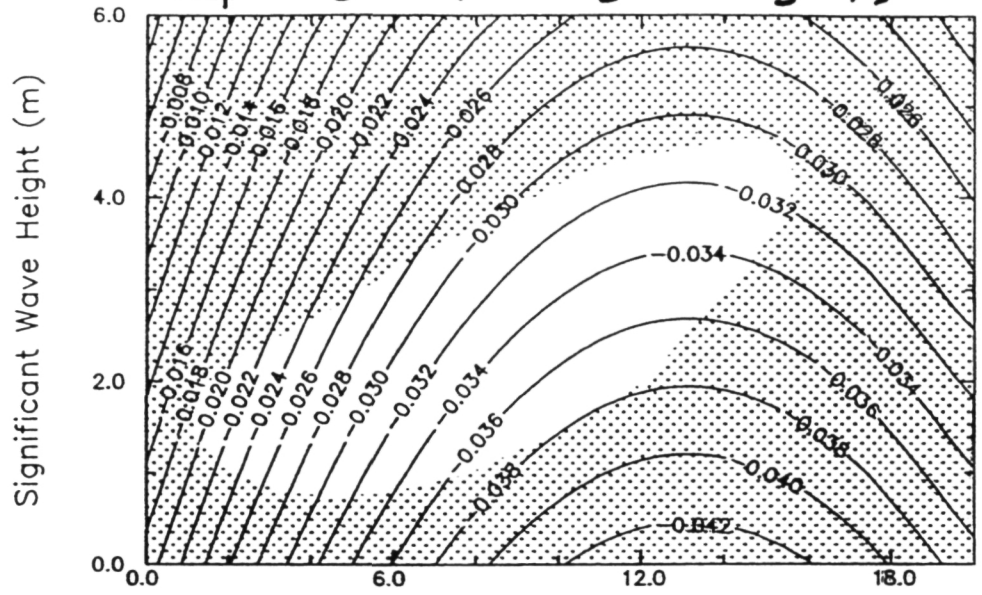
$\pm 1\sigma$ uncertainty

c



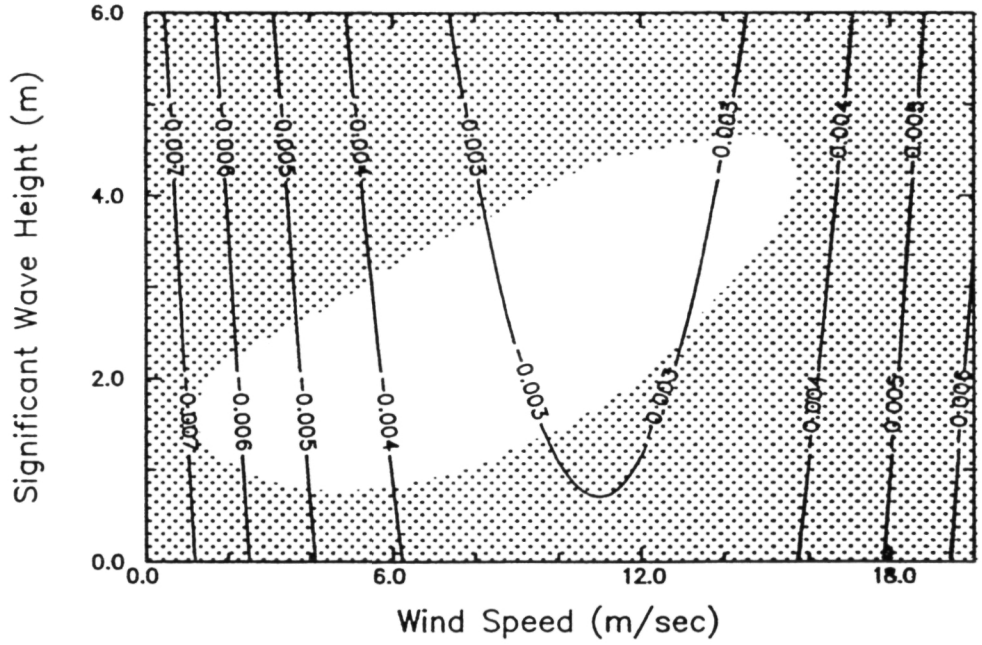
$$b_4 = a_0 + a_1 u + a_2 u^2 + a_3 H_{1/3}$$

a



Gaspar et. al coefficients

b

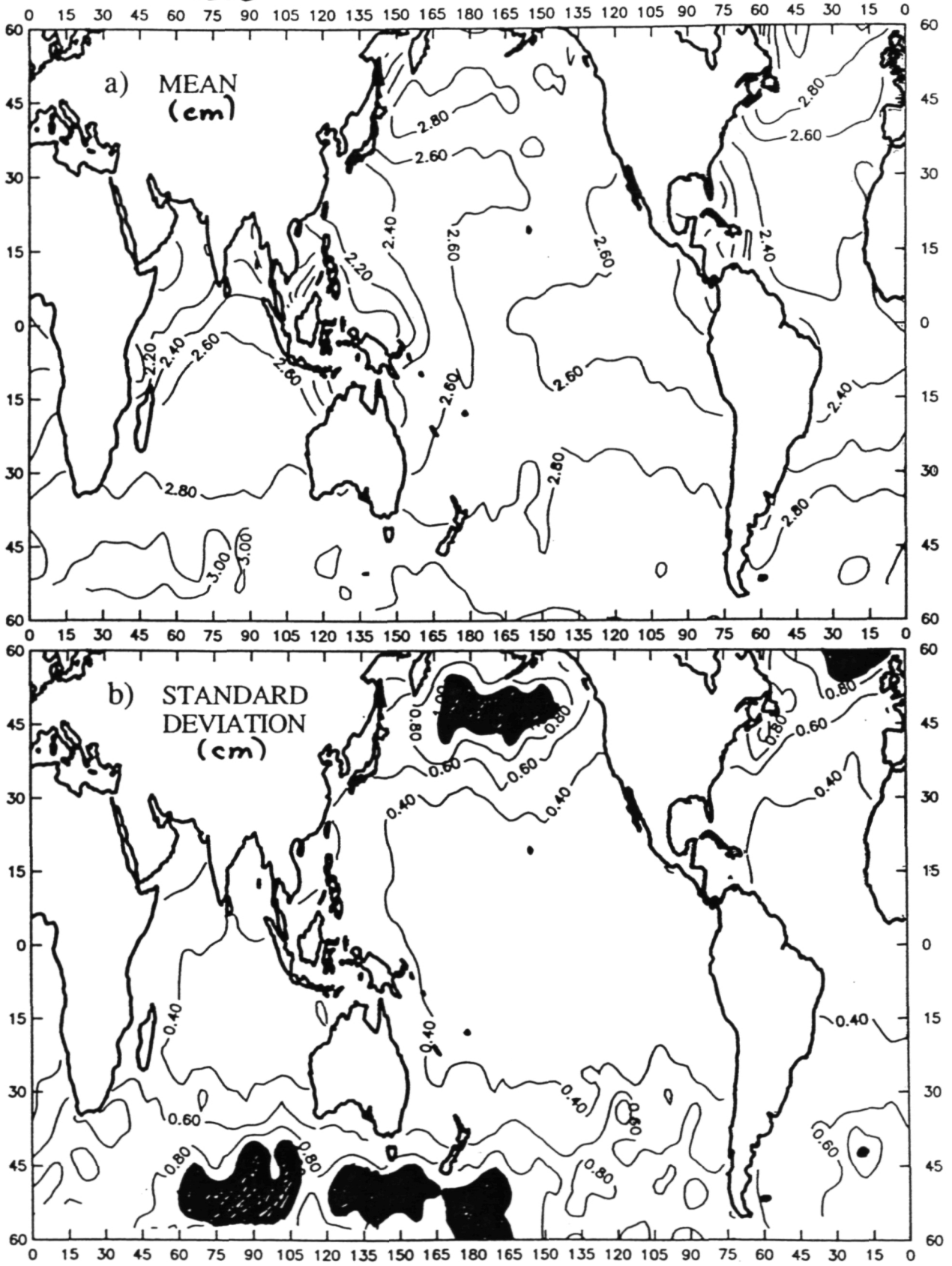


Chelton minus Gaspar et al.

MEAN AND STANDARD DEVIATION OF $[\Delta h^{(3)}_{SSB} - \Delta h^{(4)}_{SSB}]$

$$\Delta h^{(3)}_{SSB} = b_3 H_{1/3}$$

$$\Delta h^{(4)}_{SSB} = b_4 H_{1/3}$$



Conclusions

- GDR sea-state bias correction is pretty good
- sea-state bias coefficient b appears to depend on $H_{1/3}$ as well as u

$$\Delta h_{SSB} = b(u, H_{1/3}) \cdot H_{1/3}$$

Remaining Issues

- still an uncertainty of 1% $H_{1/3}$ in sea state bias correction
- still no solid theoretical basis for sea state bias correction
- difficult to estimate sea state bias parameters because all independent variables are correlated
- sea state bias correction and inverse barometer correction highly correlated
- geographical dependence of sea-state bias

RECOMMENDATIONS

- use the same sea-state bias ~~correction~~ formulation for TOPEX and POSEIDON
- replace GDR 3-parameter formulation b_3 with 4-parameter formulation b_4

$$b_3 = a_0 + a_1 u + a_2 u^2$$

$$b_4 = a_0 + a_1 u + a_2 u^2 + a_3 H_{1/3}$$

- continue theoretical work to understand the physics of the sea state bias
  - why is there an apparent inconsistency between dependencies of b on u and $H_{1/3}$?

Space
Oceanography
Group
CLS

THE OCEAN'S RESPONSE TO ATMOSPHERIC LOADING AS SEEN BY TOPEX / POSEIDON

Philippe Gaspar, CLS

With contributions from
C. Wunsch
J.F. Minster and A. Ganachaud (GRGS)
L. Fu and G. Pihos (JPL)
R. Ponte (AER)
P. Woodworth (POL)

SWT AGU / 5-9/12/94

1. COMMON KNOWLEDGE

OCEAN'S RESPONSE TO ATMOSPHERIC LOADING IS ESSENTIALLY ISOSTATIC

IB approximation :

$$IB = b(\bar{p} - p) \qquad (1)$$

$$b = \frac{1}{\rho g} \simeq 1 \text{ cm / mbar}$$

FAIR APPROXIMATION EXCEPT

➲ **FOR FORCING PERIODS SHORTER THAN ~ 2 DAYS :**

- **Theory** (e.g. Munk and Mc Donald, 1960; Dickman, 1988...)
- **Observations** (tide gauges, bottom pressure recorders) (Wunsch, 1972 ; Brown et al, 1975...).
- **Numerical simulations** (Ponte, 1991).

➲ **IN COASTAL REGIONS OR MARGINAL SEAS**

Theory and observations : Robinson (1960) ; Hamon (1966), Garrett and Majaess (1984...)

2. RESULTS FROM ALTIMETER DATA ANALYSIS

GEOSAT: Wunsch (1991), Van Dam and Wahr (1993) Hoar and Wilson (1994)

TOPEX/POSEIDON: Fu and Pihos (1994), Woodworth et al. (1994), Minster and Ganachaud (1994), Gaspar and Ponte (1994)

⇨ **COMMON TECHNIQUE: regression analysis**

Ideally $\eta = \alpha(\bar{p} - p) + e$

In practice $\Delta SSH_m = -\alpha_m \Delta p_m + e$

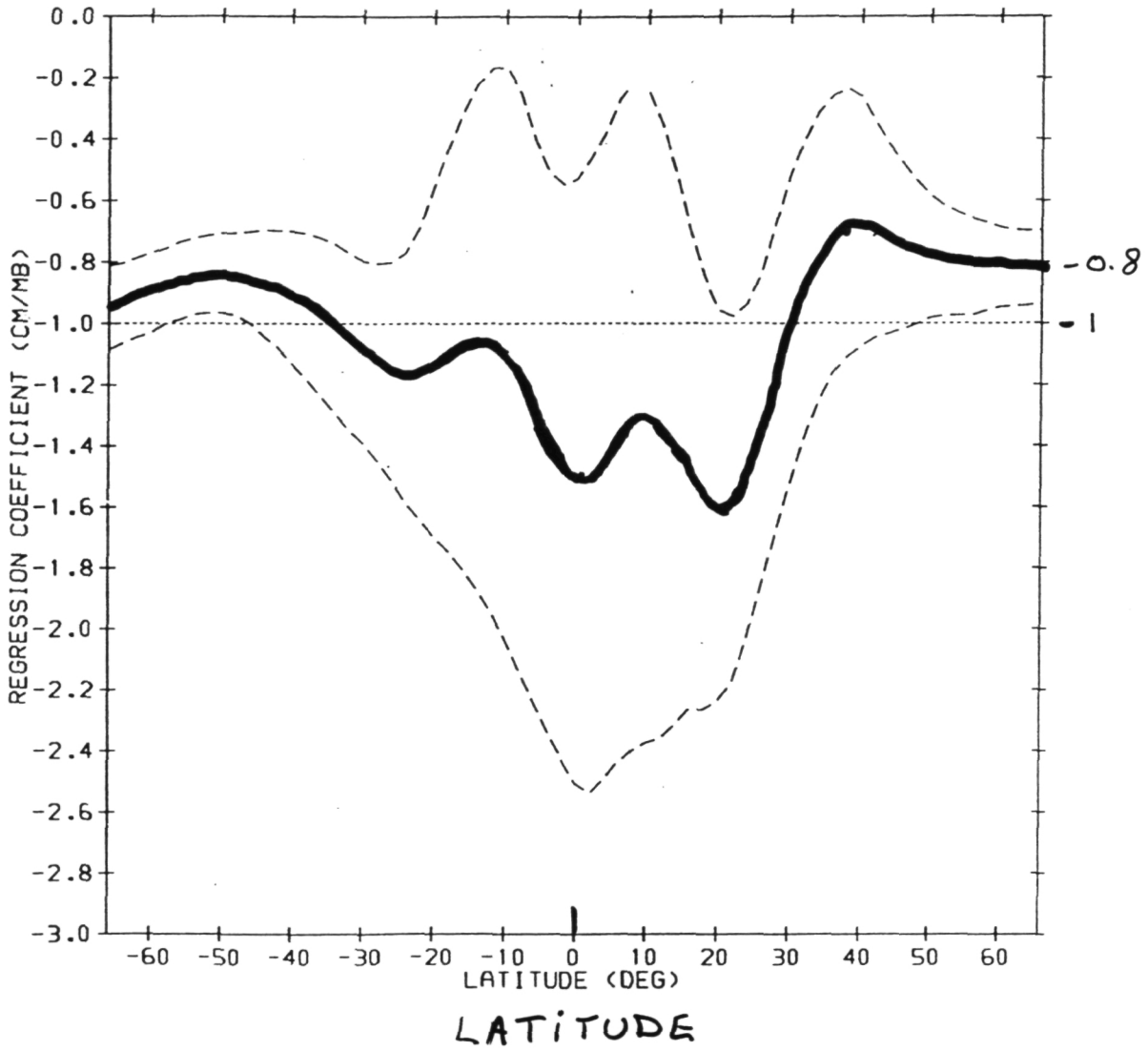
with $x = x_m + \varepsilon_x$ (true, measured, error)

$SSH = hg + \eta$

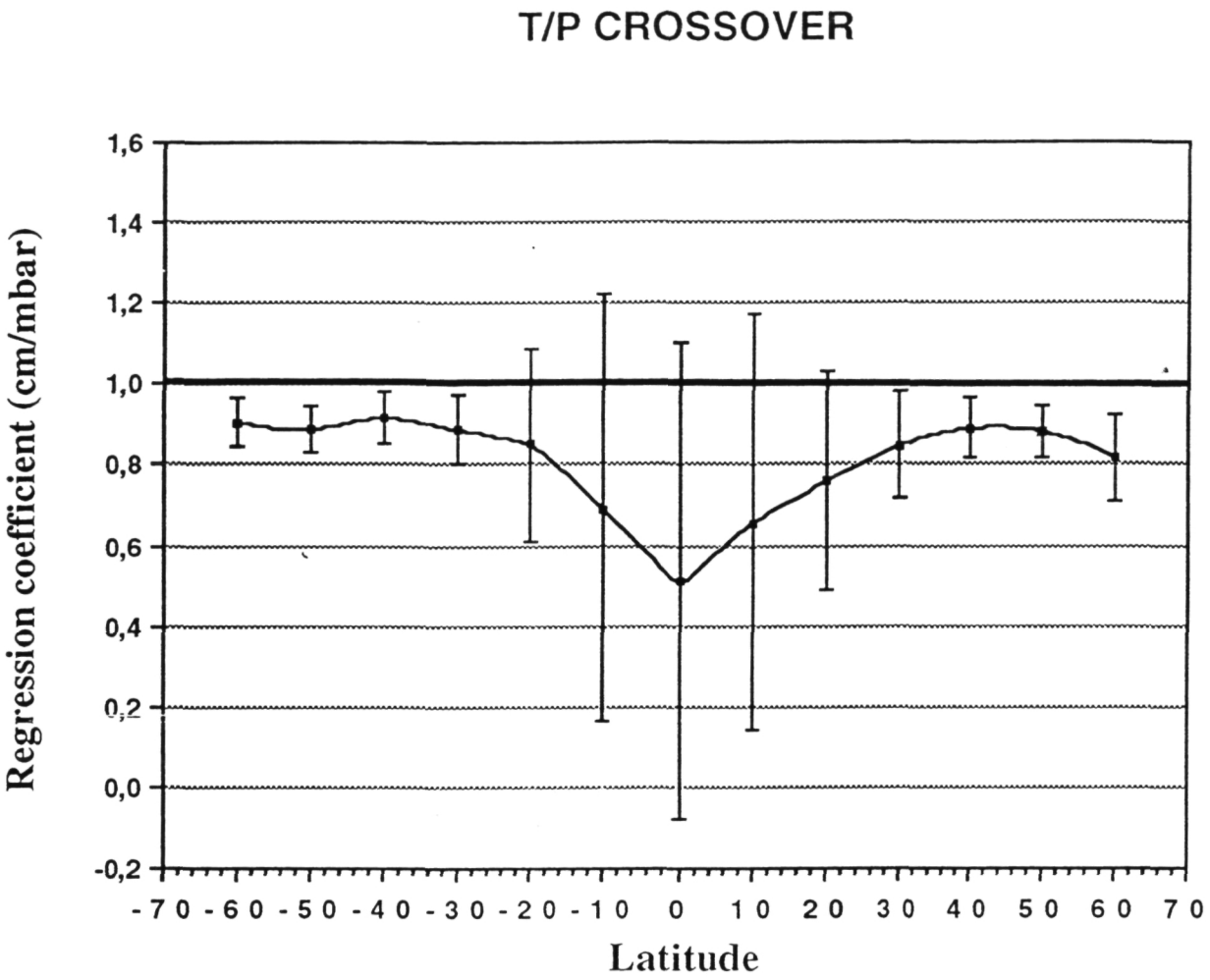
L.L.E.

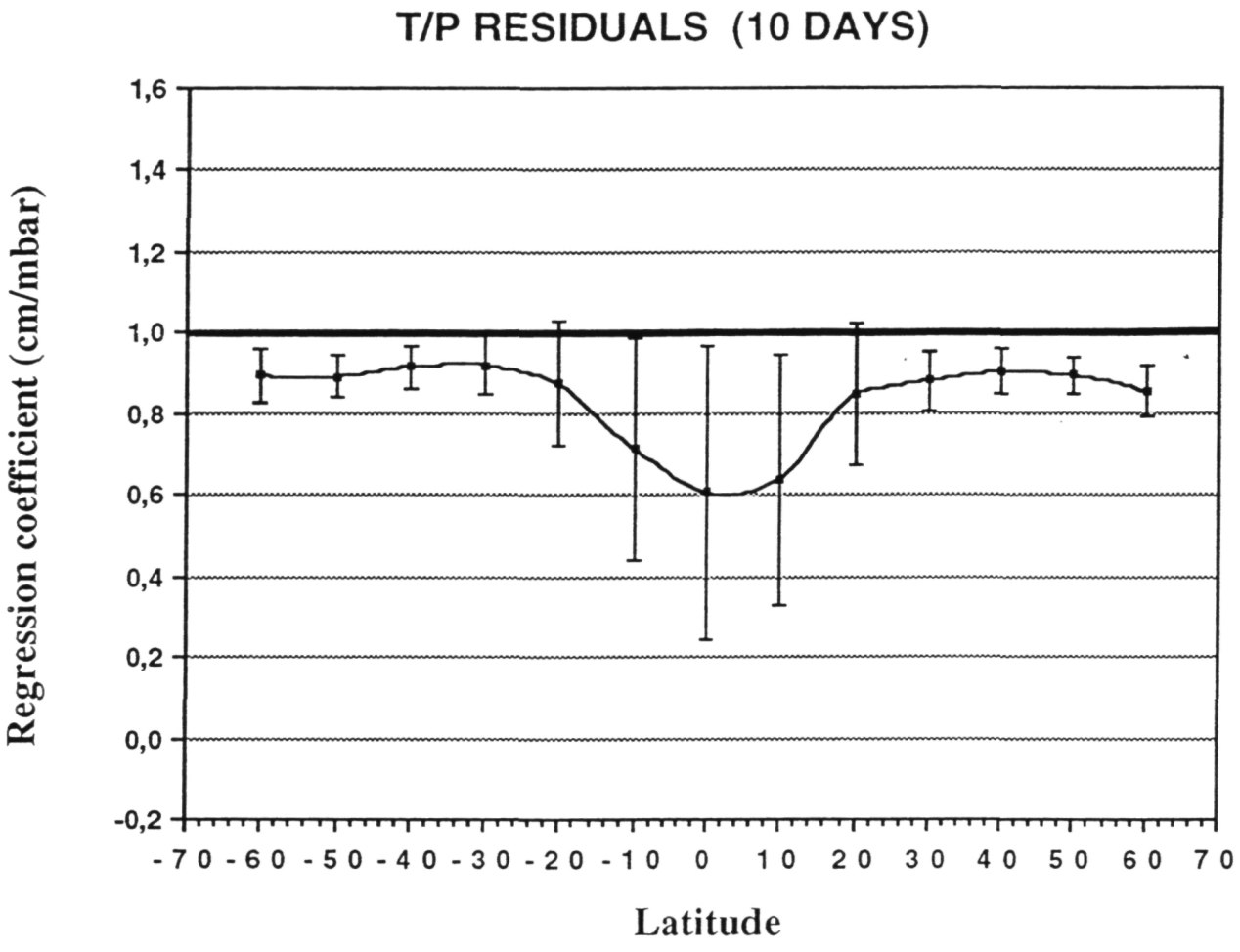
⇨

$$\alpha_m = \frac{\langle -\Delta SSH_m \, \Delta p_m \rangle}{\langle \Delta p_m^2 \rangle} \qquad (2)$$



Fu and Pihos (1994)


T/P CROSSOVER
Regression coefficient (cm/mbar)
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
-0,2
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70
Latitude


T/P RESIDUALS (10 DAYS)
Regression coefficient (cm/mbar)
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
-0,2
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70
Latitude

3. ANALYSIS OF THE REGRESSION COEFFICIENT

Define η', the "adjusted" sea level

$$\eta' = \eta - IB$$

Then :

$$\boxed{\Delta SSH_m = \Delta\eta' - b\,\Delta p_m - b\,\Delta\varepsilon_p - \Delta\varepsilon_{orb} + \Delta\varepsilon}$$

so that the regression coef. can be rewritten:

$$\alpha_m = b + \langle \Delta p_m^2 \rangle^{-1} [- \langle \Delta\eta' \Delta p_m \rangle \quad \rightarrow d\alpha_\eta : \text{non-IB signals}$$

$$+ b \langle \Delta\varepsilon_p \Delta p_m \rangle \quad \rightarrow d\alpha_p : \text{pressure errors}$$

$$+ \langle \Delta\varepsilon_{orb} \Delta p_m \rangle \quad \rightarrow d\alpha_{orb} : \text{orbit errors}$$

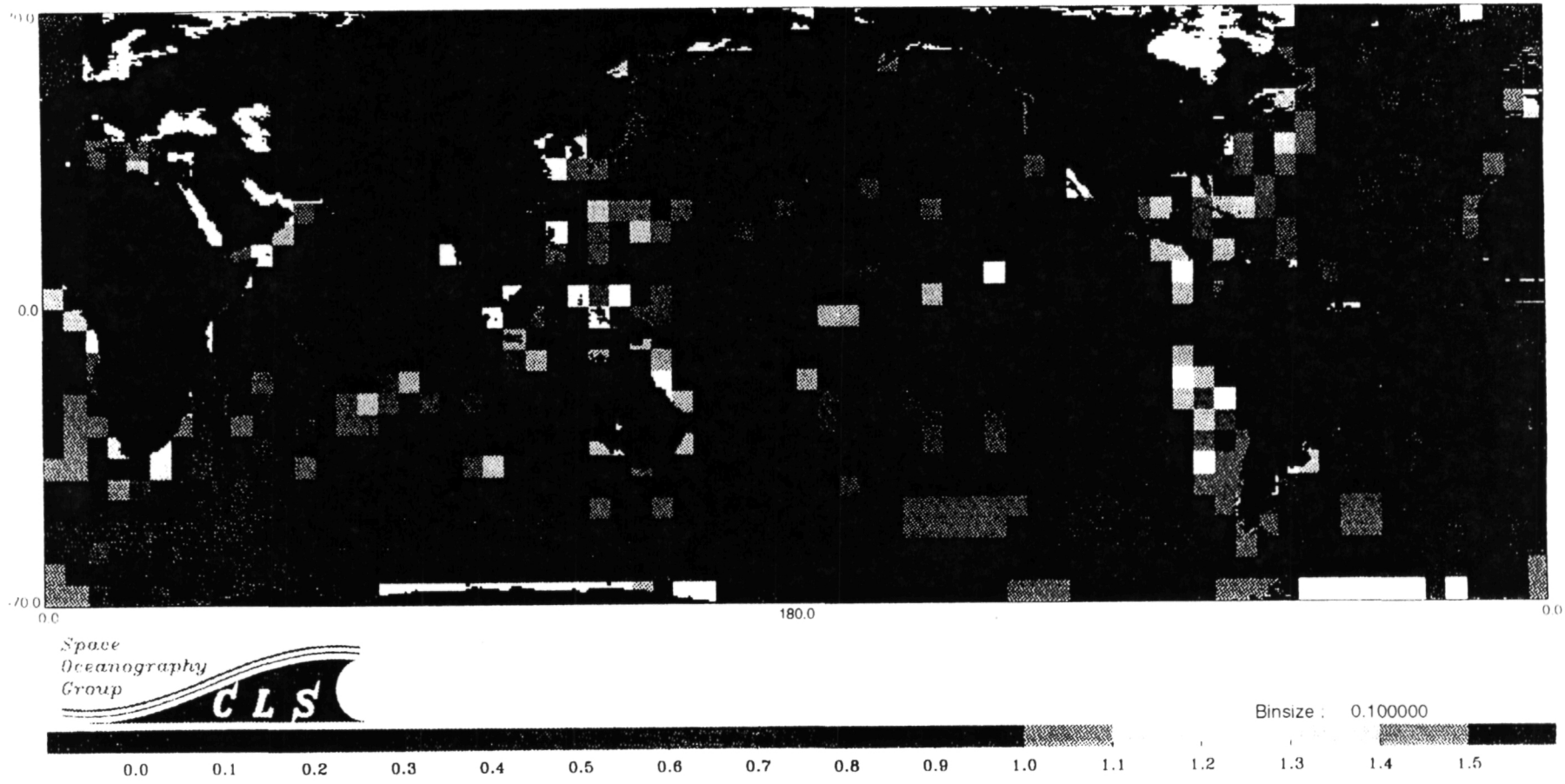
$$- \langle \Delta\varepsilon \Delta p_m \rangle] \quad \rightarrow d\alpha_h : \text{range meas. errors}$$

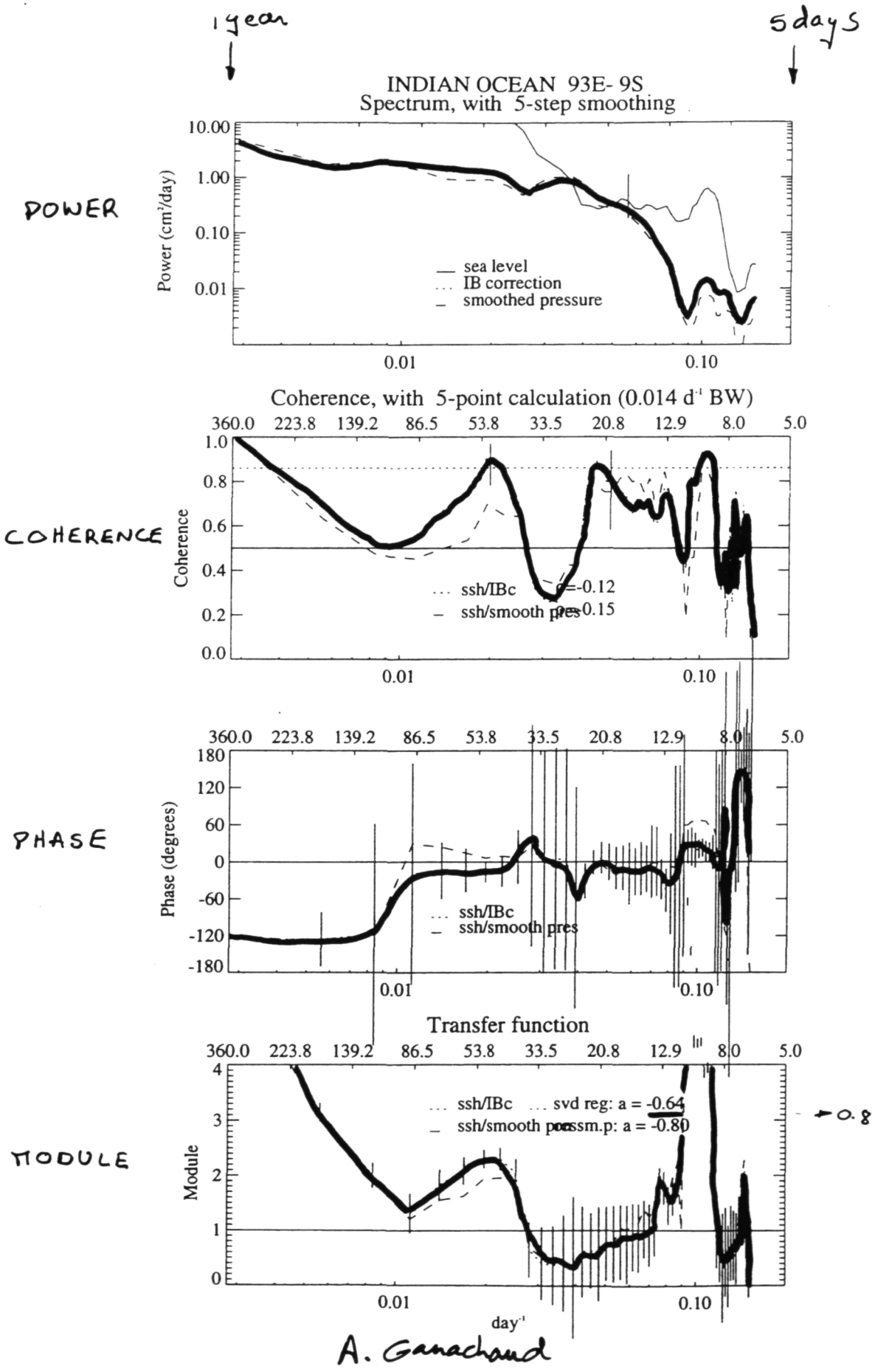
$$\alpha_m \simeq b - \frac{\langle \Delta\eta' \Delta p_m \rangle}{\langle \Delta p_m^2 \rangle} + \frac{\langle \Delta\varepsilon_{orb} \Delta p_m \rangle}{\langle \Delta p_m^2 \rangle}$$

$$\boxed{\alpha_m \simeq b + d\alpha_\eta + d\alpha_{orb}}$$

REGRESSION COEFFICIENT (CM\MB)
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
0
30
60
90
120
150
180
210
240
270
300
330
0
60
45
30
15
0
15
30
45
60

T/P RESIDUALS (10 DAYS)



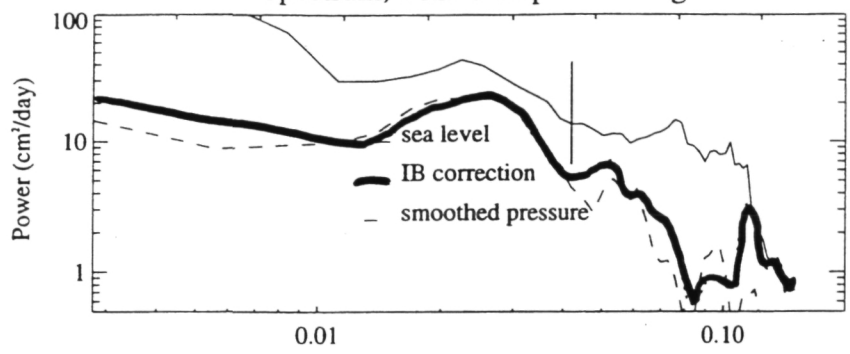

1 year
5 days
INDIAN OCEAN 93E- 9S
Spectrum, with 5-step smoothing
POWER
Power (cm²/day)
10.00
1.00
0.10
0.01
sea level
IB correction
smoothed pressure
0.01
0.10
Coherence, with 5-point calculation (0.014 d⁻¹ BW)
360.0 223.8 139.2 86.5 53.8 33.5 20.8 12.9 8.0 5.0
COHERENCE
Coherence
1.0
0.8
0.6
0.4
0.2
0.0
ssh/IBc
ssh/smooth pres
c=-0.12
c=0.15
0.01
0.10
PHASE
Phase (degrees)
180
120
60
0
-60
-120
-180
ssh/IBc
ssh/smooth pres
Transfer function
MODULE
Module
4
3
2
1
0
ssh/IBc
ssh/smooth pres
svd reg: a = -0.64
sm.p: a = -0.80
0.8
day⁻¹
A. Ganachaud

1 year

5 days

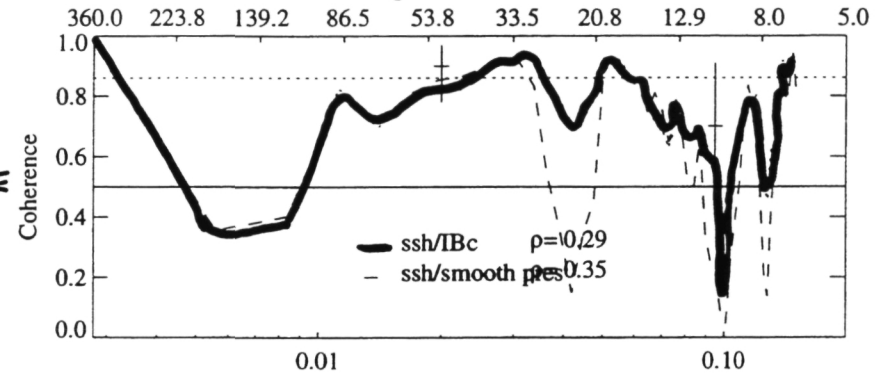
GULF-STREAM 63W-37N
Spectrum, with 5-step smoothing

POWER

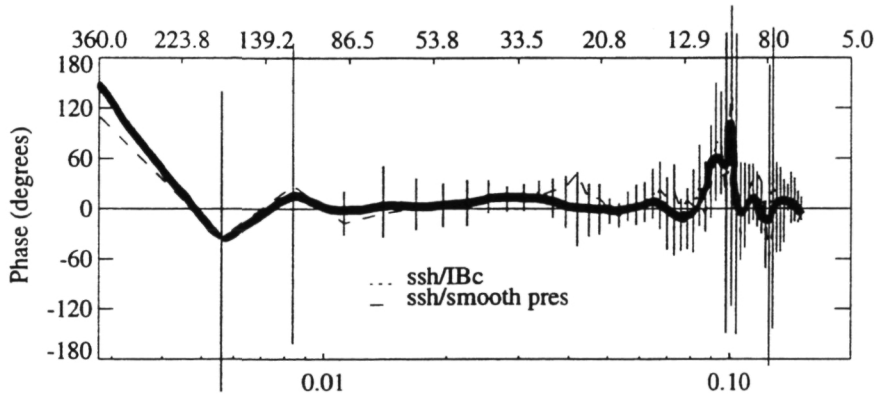


Coherence, with 5-point calculation (0.014 d⁻¹ BW)

COHERENCE

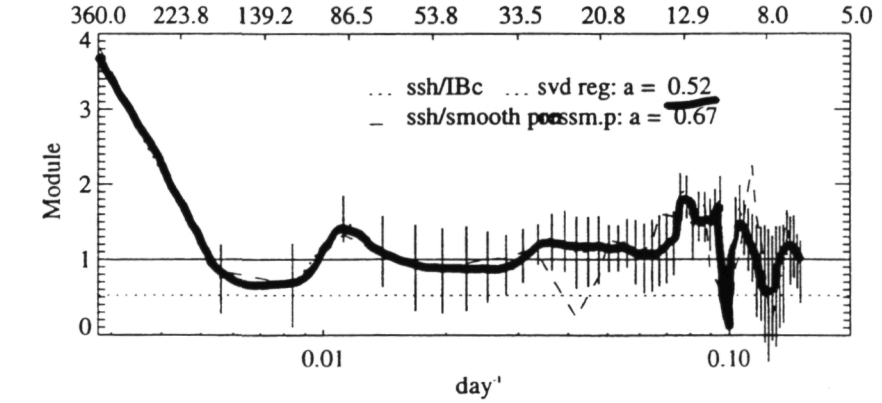


PHASE



Transfer function

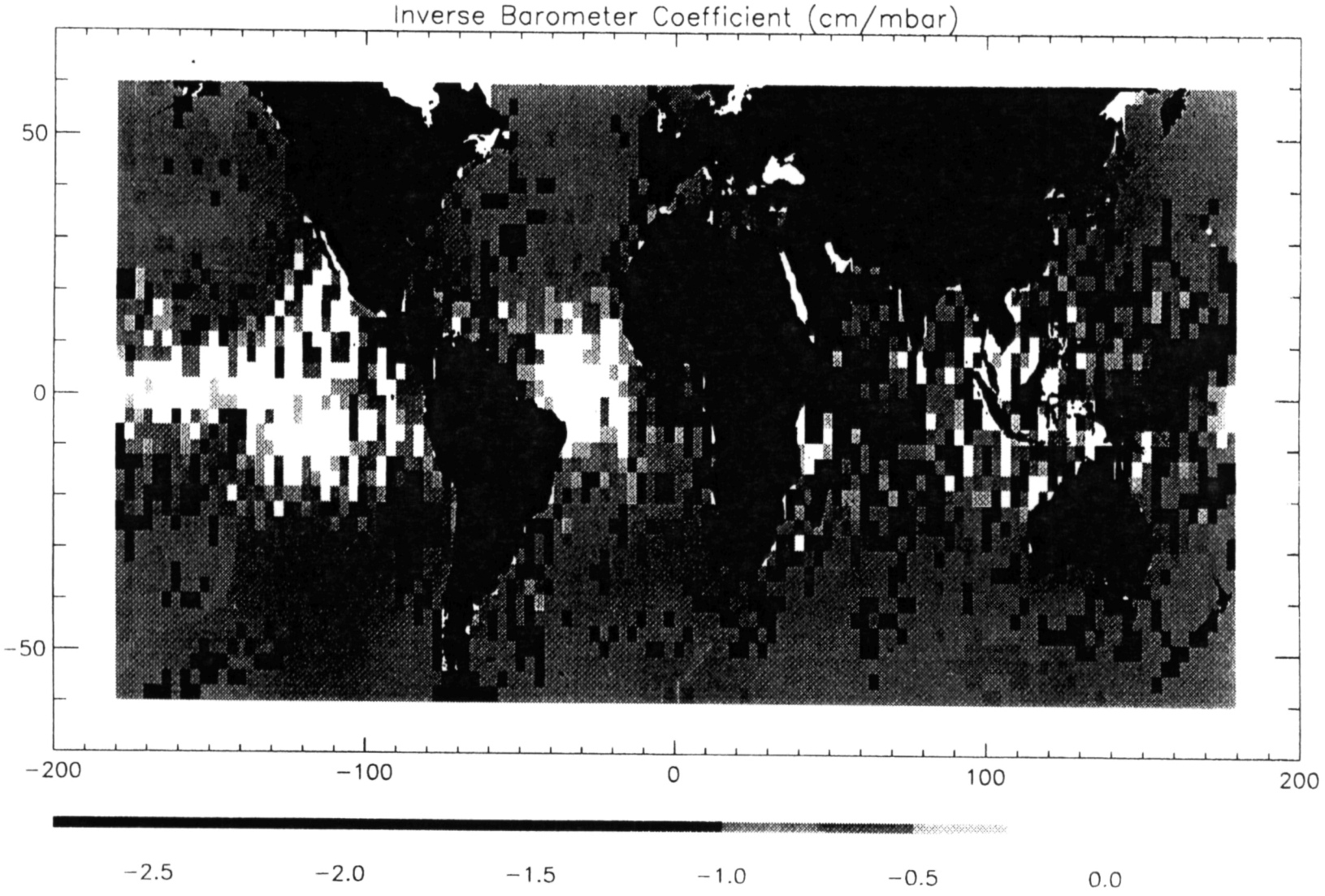
MODULE



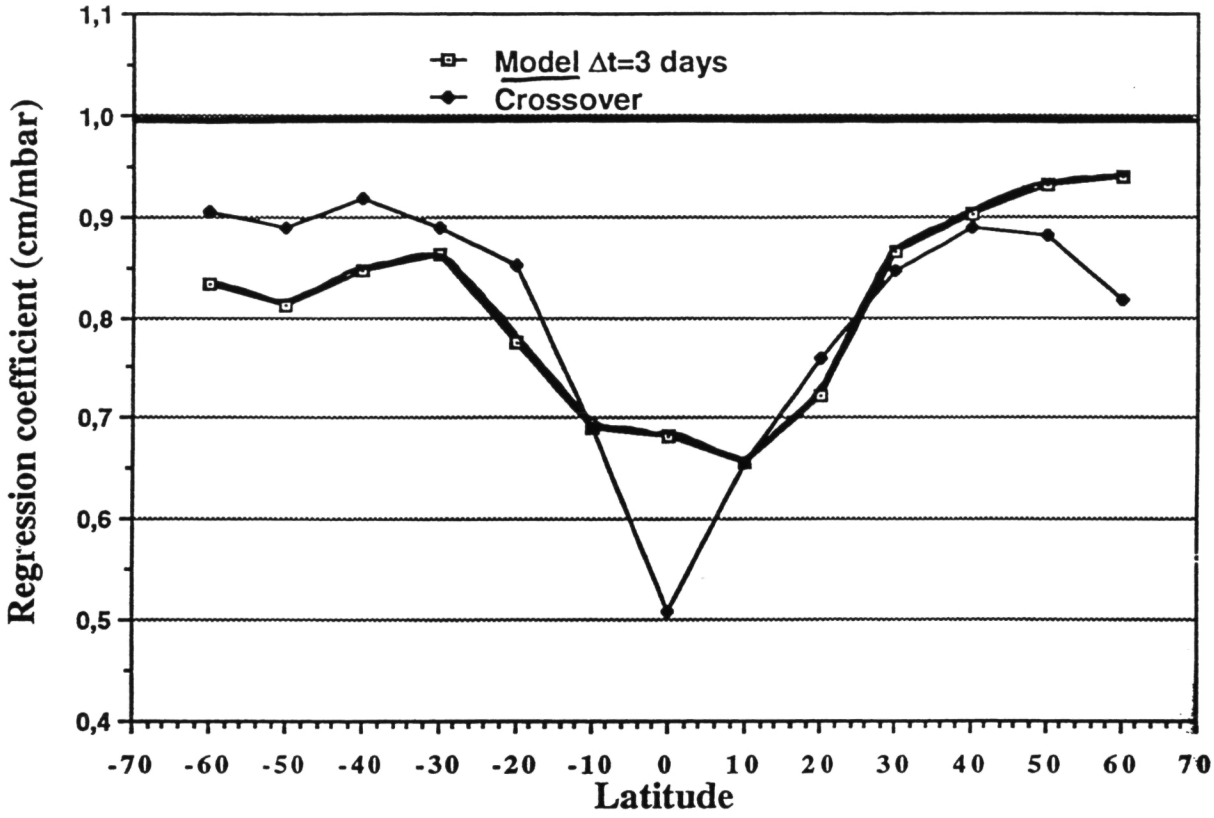
→ 1.01

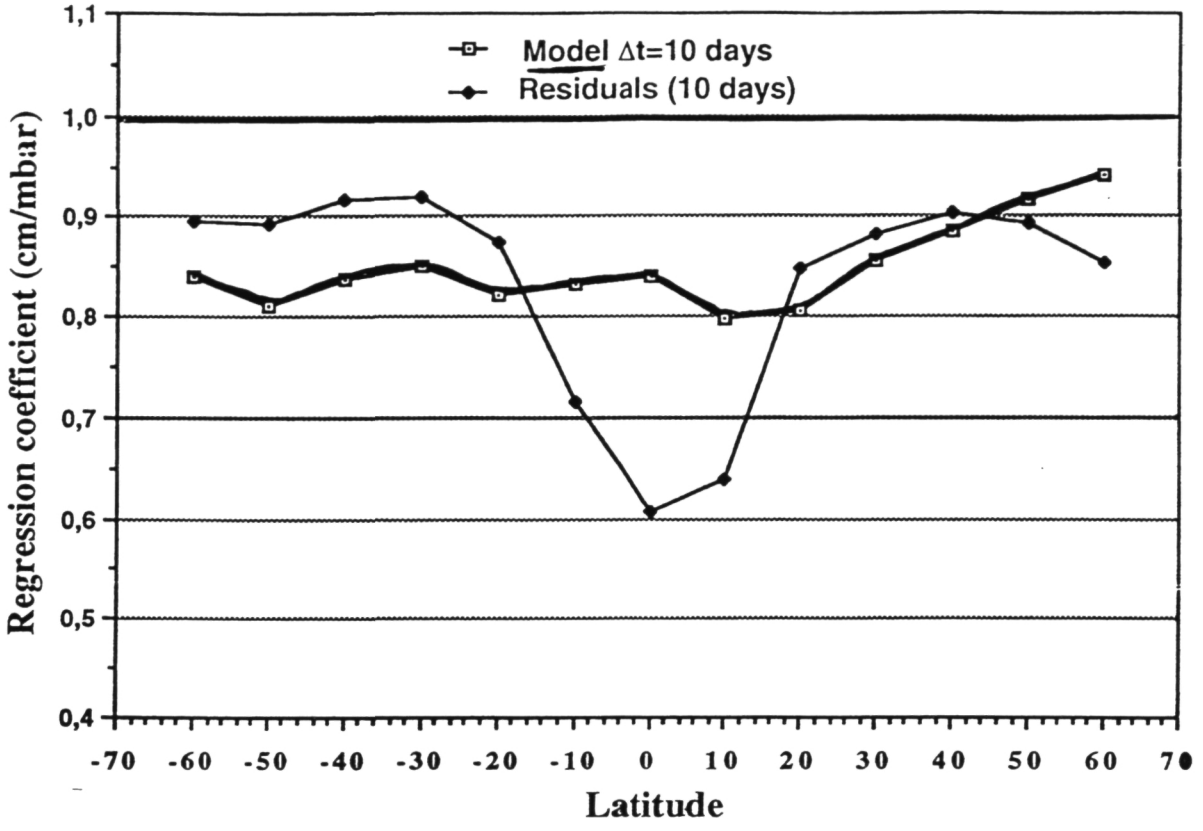
A. Ganachaud

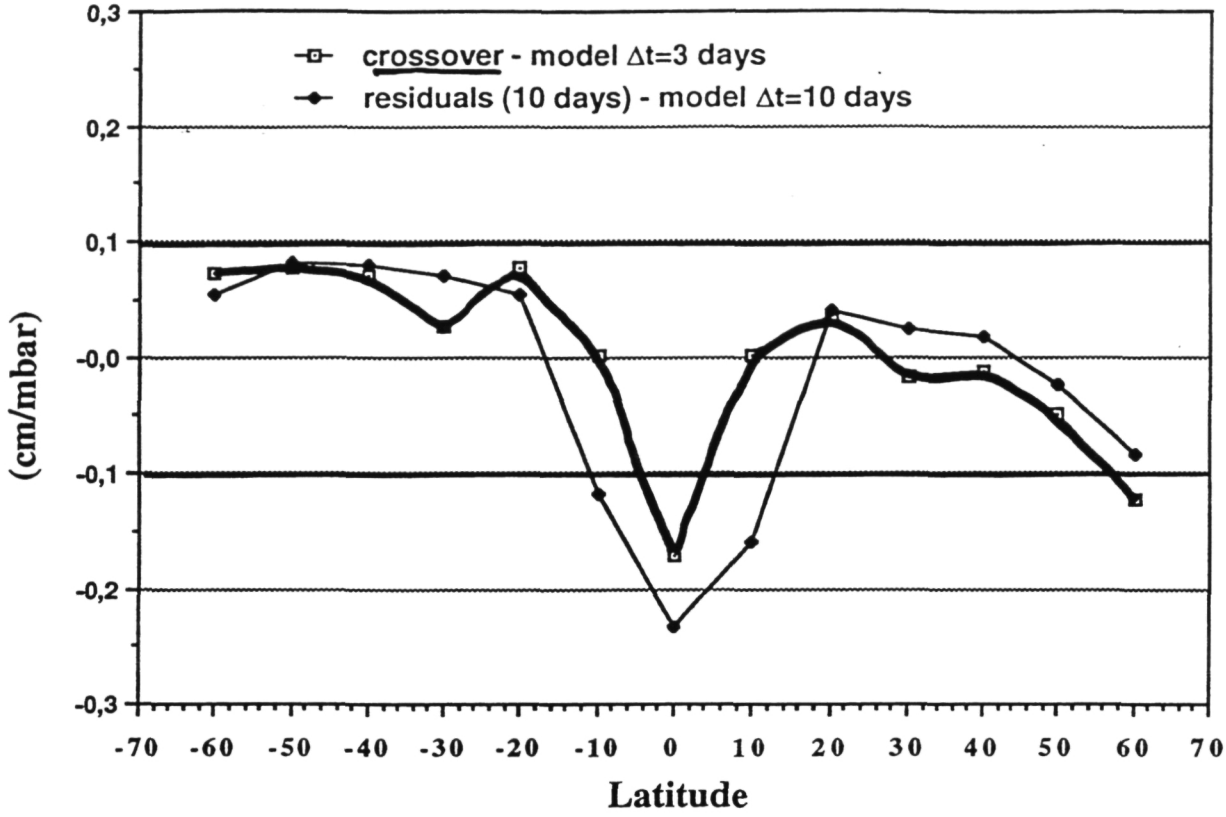
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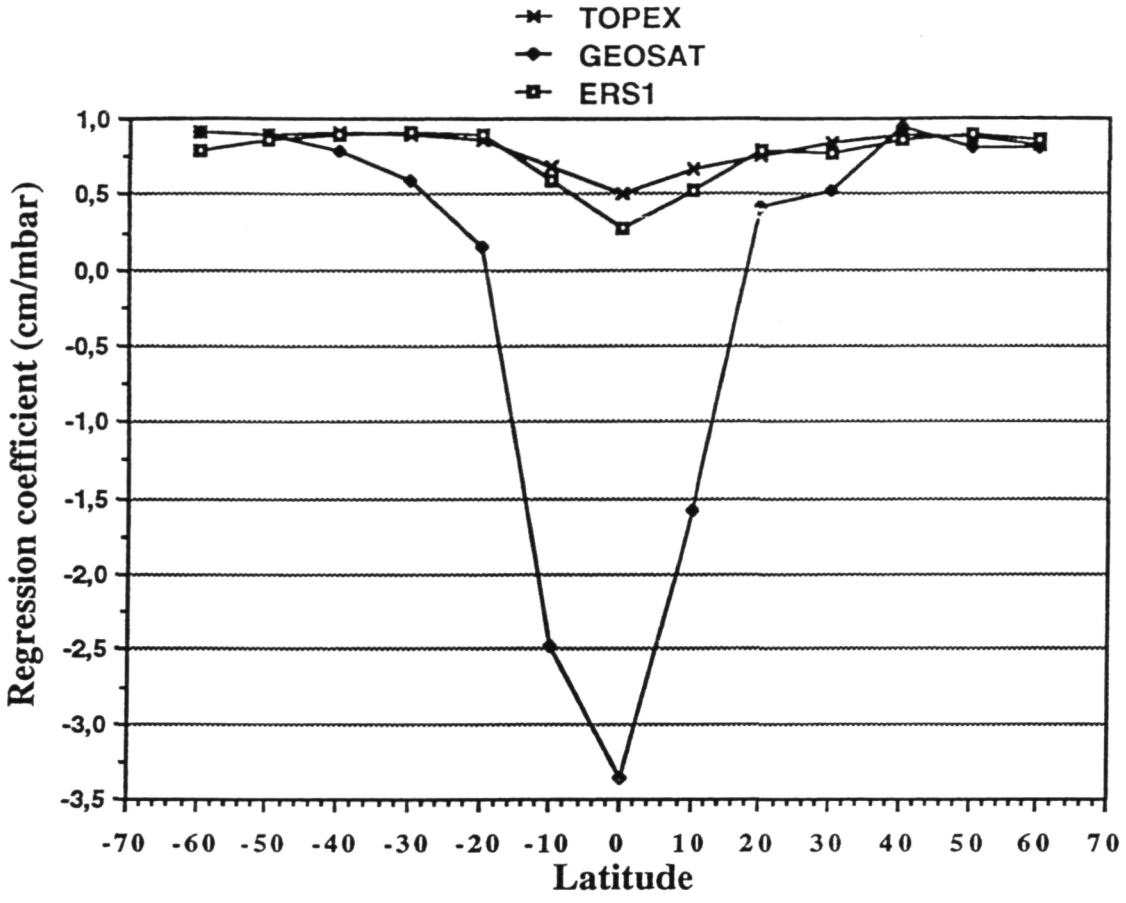


C-3


Model Δt=3 days
Crossover
Regression coefficient (cm/mbar)
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70
Latitude


Model Δt=10 days
Residuals (10 days)
Regression coefficient (cm/mbar)
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70
Latitude


crossover - model Δt=3 days
residuals (10 days) - model Δt=10 days
0,3
0,2
0,1
-0,0
-0,1
-0,2
-0,3
(cm/mbar)
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70
Latitude


TOPEX
GEOSAT
ERS1
Regression coefficient (cm/mbar)
1,0
0,5
0,0
-0,5
-1,0
-1,5
-2,0
-2,5
-3,0
-3,5
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70
Latitude

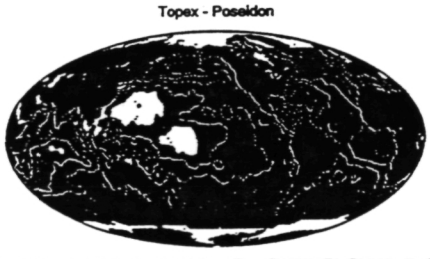
CONCLUSIONS

- Ocean response to p hidden among other dynamical signals empirically correlated with p.
- Most of these other signals are attenuated by data differencing with small Δt.
- Regressions with such data exhibit IB response attenuated by η_w anticorrelated with pressure signals.
- Regressions results agree with Ponte simulations (within 1-2 mm/mbar)
- Orbit errors might explain part of the difference
- Analysis focussed on short term response to p. Use of constant p is legitimate. The ocean adjustment over longer periods (> months) remains to be studied.

AVISO : KEEPS ON GOING . . .

Patrick Vincent (*), Frederique Blanc (+)
CNES, Earth Science and Environment Division
(+) CLS, Space Oceanography Group
Toulouse, France

A MULTI-SATELLITE DATA CENTER DEDICATED TO SPACE OCEANOGRAPHY



A DATA PROCESSING, ANALYSIS AND DISTRIBUTION SYSTEM

AVISO - SWT, December 1994

P. VINCENT, F. BLANC

aviso
ALTIMETRIE

FIRST MISSION

TOPEX / POSEIDON MISSION

- **PROCESSING**
  TOPEX/POSEIDON SATELLITE DATA

- **VERIFYING THEIR ACCURACY**

- **MAKING THEM AVAILABLE**
  TO THE SCIENTIFIC COMMUNITIES

AVISO - SWT, December 1994 P. VINCENT, F. BLANC

AVAILABLE PRODUCTS

Basic products

Level 2 products	Media	Dissemination
IGDR-T	mailbox	On request
IGDR-P	mailbox	On request
GDR-Ms	CD ROM	Systematic
Crossover points	CD ROM	Systematic
NASA orbit ephemeris	CD ROM	Systematic
CNES orbit ephemeris	CD ROM	Systematic
Newsletters (July 1992, May 1993 and September 1994)	Document	Systematic

AVAILABLE PRODUCTS

New products

Other products	Media	Dissemination
Validated GDR-Ms	CD ROM	On request
Reduced GDR-Ms	CD ROM	On request
Sea level variability files	CD ROM	On request
ERS-1 TOPEX/POSEIDON enhanced GDRs	CD ROM	On request
Extracted products (GDR-Ms, winds and waves, crossover points, validated GDR-Ms, reduced GDR-Ms, sea level variability)	CD ROM	On request
Tidal models (GSFC orthotide model, University of Texas model, GSFC_TUD model, UMR39/GRGS model, LEGI_IMG model, Oregon State University model and GSFC94A Proudsman functions model)	CD ROM	Systematic

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aviso
ALTIMETRIE

NEW SERVICES

IMPLEMENTED IN 1994

- **DISTRIBUTION OF DATA PRODUCTS (NEW) ON REQUEST**
- **MOSAIC INFORMATION SERVER**

STATUS :

OPERATIONAL

PRESENT DISTRIBUTION SYSTEM :

CD ROMS

CD ROM STRUCTURE :

COMMON TO ALL PRODUCTS

AVISO - SWT, December 1994 P. VINCENT, F. BLANC

ORIGINAL PAGE IS
OF POOR QUALITY

INFORMATION SERVER

URL "http://192.134.216.41"

CURRENT FEATURES

THE TOPEX/POSEIDON MISSION

General Overview,
The payload instruments,
The satellite orbit,
The data processing operations,
The post-launch error budget.

THE AVISO/ALTIMETRY MISSION

The AVISO team,
TOPEX/POSEIDON activities,
Available products.

INFORMATION ON LAST PROCESSED TOPEX/POSEIDON CYCLE

(updated every cycle or two cycles)

General information
Validation results
Global mappings

- **OUTLINE OF T/P RESULTS**

Synthesis of validation results
Synthesis of scientific results

- **BIBLIOGRAPHY**

aviso
ALTIMETRIE

- **GLOSSARY**

aviso
ALTIMETRIE

PHILOSOPHY
ON NEW PRODUCTS

FIRST FUNCTION POSSIBLE TO ACHIEVE :

- **PERFORM A CENTRAL ARCHIVE OF ALL TYPES OF NEW PRODUCTS : either they come from the direct environments of the AVISO team or from external entities**

HOW TO SATISFY IN A TIMELY MANNER TO A DISTRIBUTION FUNCTION ?

- **FOR QUICK DISTRIBUTION: FTP PROTOCOL RECOMMENDED**

- **FOR NON-REAL TIME DISTRIBUTION: CD ROM (like any physical media)**

AVISO - SWT, December 1994 P. VINCENT, F. BLANC

aviso
ALTIMETRIE

DISTRIBUTION

SOLUTIONS TO PERFORM ADAPTED DISTRIBUTION

- **IMPLEMENT AN AVISO PUBLIC FTP ZONE** (MOSAIC)

- **FOR CENTERS GENERATING DATA OF PUBLIC UTILITY AND HAVING ANONYMOUS FTP**

  inform the AVISO team so that the AVISO INFORMATION SERVER can be updated to include information about new data products and FTP address to connect to.

- **GENERATION BY AVISO OF CD ROMs**

  with standard structures and formats

  to achieve

  DIFFERRED TIME DISTRIBUTION



AVISO CATALOGUE

TO BE ACCESSED PUBLICLY

ALL ALTIMETER PRODUCTS (BASIC AND NEW) CATALOGUED

POSSIBLITIES TO PERFORM DATA REQUESTS

TARGET DATE :

JUNE 1995

AVISO - SWT, December 1994 P. VINCENT, F. BLANC

CONCLUSION

- CONTINUE TO

  PRODUCE
  VALIDATE
  ARCHIVE
  DISTRIBUTE

  TOPEX/POSEIDON DATA

- CONTINUE TO

  PROMOTE THE MISSION
  THROUGH NEWSLETTERS
  AND INFORMATION SERVER

- BEGINNING OF 1995

  MAKE AVAILABLE
  ALL NEW PRODUCTS LISTED

- BY JUNE 1995:

  PERFORM CATALOGUING
  OF PRODUCTS

JET PROPULSION LABORATORY
PHYSICAL OCEANOGRAPHY
DISTRIBUTED ACTIVE ARCHIVE CENTER

TOPEX/POSEIDON ACTIVITIES

Donald J. Collins
MANAGER

SCIENCE WORKING TEAM MEETING
DECEMBER 4, 1994

STATUS OF PO.DAAC

- VERSION 0: WORKING PROTOTYPE WITH OPERATIONAL ELEMENTS
  - OPERATIONAL: AUGUST, 1994
- PO.DAAC MOSAIC HOMEPAGE
  - http://seazar.jpl.nasa.gov/

MISSION BASELINE

•	ERS-1	L: 7/91
	• ALTIMETER CD-ROM	7/94
•	TOPEX/Poseidon	L: 8/92
•	ERS-2	L: 12/94
•	NSCAT/ADEOS	L: 2/96
•	SeaWinds	L: 2/99
•	EOS ALTIMETER	L: 6/99
•	ENVISAT	L: 2000
•	METOP	L: 2000

STATUS

- ARCHIVE AND DISTRIBUTE THE STANDARD DATA PRODUCTS FROM THE TOPEX/POSEIDON MISSION TO THE SCIENCE WORKING TEAM, AND THE SCIENTIFIC COMMUNITY IN SUPPORT OF THE MISSION.
  - QUICK LOOK BULLETIN BOARD
    - DAILY PASS FILES FOR EACH CYCLE
  - LIMITED DISTRIBUTION OF SDR DATA
  - DISTRIBUTING GDR DATA TO SWT
  - MERGED GDR CD-ROM DATA PRODUCT
    - CYCLES 1 - 68 DISTRIBUTED (63 - 64)
    - CYCLES 63 - 64, 69 - 72 AT SONY FOR CD-ROM PRODUCTION
    - CYCLES 73 - 74 TO BE PRODUCED BY THE END OF THIS WEEK
  - LEVEL 3 DATA PRODUCTS UNDER DEFINITION
    - GRIDDED MAPS ON MOSAIC
      - http://topex-www.jpl.nasa.gov/
      - http://podaac-www.jpl.nasa.gov/topex/
    - TIDE PRODUCTS ON FTP AND MOSAIC
      - http://seazar.jpl.nasa.gov/tides.html

FUTURE ACTIVITIES

- REPROCESSING OF THE MERGED GDR
  - WHAT CONDITIONS INITIATE REPROCESSING
    - GROSS ERROR
    - ACCUMULATION OF SMALLER ERRORS
    - DEVELOPMENT OF NEW TIDAL MODELS, MSS, GEOID, ORBITS, ETC.
- ADDITIONAL DATA PRODUCTS AND SERVICES

V. Zlotnicki

— NEW ORBITS, TIDES, SSB, ...

— HOW TO MAKE THEM AVAILABLE TO:

* ALTIMETRY-SAVVY USERS

→ * OTHER OCEANOGRAPHERS ←

— HOW TO MAKE CORRECTED SEA LEVEL AVAILABLE TO OTHER OCEANOG.

— HOW TO DOCUMENT NEW CORR. STRENGTHS + WEAKNESSES TO "US" AND "OTHER": WHO.

— HOW TO NAME THEM

DOCUM. PROGRAMS AS IF FOR SOMEBODY ELSE; IN SIX MONTHS ... KEEN

DELIVERY OPTIONS

① LETTER (e.g. Topex-Poseidon BIAS, Poseidon SSB)

② LETTER + FTP (· PARAMETER FILES
· PROGRAM: value (t, φ, λ)
· TEXT FILE TECHNICAL DESCRIPTION)

③ MAIL CD-ROM (· PARAM. FILES
· PROG. value (t, φ, λ)
· TEXT F. TECH DESCRIPT.)

④ NEW GDR
NEW USER MANUAL

all corrections to past data as Δ files (changes at t, φ, λ) from the GDR correction)

	WHICH CORR.	Ess Inp Nr.	WHEN available fr author	DELIVERY MODE		DOCUMENT WHO	DOCUMENT WHEN
• TIDES	W+S+LP		1/31	2			~~1/31~~
• ORBIT	TAPL/KL.		3/15			TAPL/ GSFC	
• SSB - P	4 PARAM.	E	GSFC 1/30	1	—	G	✓
- T	4 PARA.	I	GSFC 1/30	1	"	G	✓
• BIAS - P	?	E	~~GSFC~~ LETR 2/15	1		LF	
- T	?	E	~~GSFC~~ LETR 2/15	1		LF.	
- IONO-P			=	1		LF	
• DRIFT - P				1			
- T	HAYNE	N		1			
• INV BAR	—	—	—		—		—
• MSS	—	N	—		—		—
• GEOID	NEUTRAL PAUL.	JGM-3 1OSU91A I	1/31				1/31
• RETRACKED-T		N					

WHO WILL "APPROVE" "RECOMMENDED PRODUCTS"

Ess Imp Nice	WHO	WHEN	WHO DOCUMENT.

GDR

SLDR

SLDR:

- TIME, LAT, LON, SEALEVEL − 93 (BEST CORR.), IBAR, TIDE
- 3 SECOND AVE
- ALONGTRACK DATA
- 4 MB / 10 DAY
- GOOD MANUAL / TECH REPORT w' WEAKNESSES, WARNINGS, ...

BEYOND TOPEX-POSEIDON

THE FRENCH PROPOSED STRATEGY

B-196

ALAIN RATIER

CNES, DIRECTORATE OF PROGRAMMES

TOPEX-POSEIDON SWT MEETING
SAN FRANCISCO, DECEMBER 4, 1994

cnes

TOPEX/POSEIDON: A UNIQUE HERITAGE

SUCCESS STORY/EXAMPLARY COOPERATION BETWEEN *THREE* PARTNERS :

NASA, CNES AND THE INTERNATIONAL SCIENCE COMMUNITY (WOCE/SWT)

TECHNOLOGY, PROJECTS, AGENCIES RESPONSIVE TO USER REQUIREMENTS

MISSION PARAMETERS INCLUDING ORBIT SELECTED BY SWT FOR OPTIMIZATION

ALGORITHMS, PRODUCTS, CAL/VAL PLAN DEFINED BY/WITH SWT

ACCESS/DATA POLICY DEFINED WITH THE SWT, INCLUDING IGDR

OUTSTANDING TECHNICAL AND WORLDWIDE SCIENTIFIC SUCCESS

UNPRECEDENTED, *FULLY PROVEN* PERFORMANCES : 4.7 CM RMS, INTERNAL CONSISTENCY IN THE MM RANGE

INTERNATIONAL, INTEGRATED RESEARCH STIMULATED/DEVELOPED:

COMBINATION OF IN SITU OBSERVATION NETWORK, SPACE DATA, NUMERICAL MODELS

ASSIMILATION OF SPACE DATA INTO MODELS FOR MONITORING AND PREDICTION

cnes

REQUIREMENTS FOR FOLLOW-UP MISSIONS

CONTINUITY FROM SAME ORBIT WITH AT LEAST SAME ACCURACY ESSENTIAL TO :

DEVELOPMENT OF MONITORING AND PREDICTION CAPABILITIES

PRE-OPERATIONAL EL NINO PREDICTION

INTERANNUAL VARIABILITY, LARGE SCALE CIRCULATION, HEAT FLUX ANOMALIES IN THE CONTEXT OF ADDITIONAL GREENHOUSE EFFECT

OCEAN DYNAMICS/CARBON CYCLE COUPLING : INTEGRATED APPROACH NEEDED

GLOBAL MEAN SEA LEVEL MONITORING

RECOGNIZED RELEVANCE TO INTERNATIONAL INITIATIVES/PROGRAMMES

WCRP: WOCE, TOGA, CLIVAR (*EXPLICIT* SUPPORT BY WOCE INTERNATIONAL)

IPCC, GCOS/GOOS (RECOMMENDED BY RIO UNCED CONFERENCE AND 2ND WORLD CLIMATE CONFERENCE)

THE FRENCH PROPOSED STRATEGY: TPFO AND GOOS

SUPPORT AND INVOLVEMENT OF FRENCH USER ORGANIZATIONS

TPFO FIRST PRIORITY OF CNES SCIENCE ADVISORY COMMITTEE

HIGH LEVEL FRENCH PROGRAMME COMMITTEE FORMED WITH METEO-FRANCE, IFREMER, ORSTOM, CNRS CHAIRED BY CNES

PROPOSED STRATEGY

INTEGRATION OF TPFO INTO A US-FRENCH CONTRIBUTION TO GOOS (INCLUDING OTHER, NON-SPACE OBSERVING SYSTEMS)

CLIMATE RESEARCH-MONITORING, MARINE METEOROLOGY : PRE-OPERATIONAL OCEANOGRAPHY

TPFO AS A SERIES WITH REAL TIME CAPABILITY, NON DISCRIMINATORY ACCESS

cnes

FRENCH CONTRIBUTION TO TPFO: STATUS AND PERSPECTIVES

COMPETITIVE INDUSTRIAL PHASE A STUDIES AT SATELLITE LEVEL : REVIEW ON 14/12

PHASE B APPROVED/FUNDED IN FY95, TO START AFTER PHASE A COMPLETION

BACKGROUND/PERSPECTIVES FOR PHASE C/D DECISION

TPFO FIRST PRIORITY OF CNES SCIENCE ADVISORY COMMITTEE

SPOT-5A/B ALREADY DECIDED : NEXT NEW START WILL BE TPFO

DECISION EXPECTED NOT BEFORE FRENCH PRESIDENTIAL ELECTION (MAY 95)

cnes

Appendix C

Abstracts Presented in AGU Fall Meeting

TOPEX/POSEIDON SESSION (U05)

******* ORAL SESSION I *******

Co-Chairs:

L.-L. Fu,
Jet Propulsion Laboratory
4800 Oak Grove Drive, Pasadena
CA 91109
Tel: 818-354-8167

Y. Menard
Centre National d'Etudes Spatiales
18 Ave. Edouard Belin
31055 Toulouse Cedex
France, Tel: 33 61 27 48 72

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1. (INVITED) "TOPEX/POSEIDON and the Oceanic General Circulation," C.Wunsch.

2. (INVITED) "New World Ocean Tide Solutions from TOPEX/POSEIDON," C. Le Provost, P. L. Woodworth and C. K. Shum.

3. (INVITED) "Geodetic and Geodynamic Contributions of TOPEX/POSEIDON," B. D. Tapley.

4. "The TOPEX/POSEIDON Mission: Results from the First Two Years," R. S. Nerem, C. J. Koblinsky, S. M. Klosko, K. E. Rachlin and R. G. Williamson.

5. "Time-Varying Sea Surface Topography Observed by TOPEX/POSEIDON Altimetry," D. P. Chambers, B. D. Tapley, C.K. Shum and J.C. Ries.

6. "Inferring Changes in Relative Heat Storage from TOPEX Sea Level Height Residuals," W. B. White.

7. "Length Scales of Sea Level Variability from TOPEX/POSEIDON and the NPS 1/4< Numerical Model," V. Zlotnicki, J. McClean and A. J. Semtner.

8. "Basic Statistics of Spatio-Temporal Variations of Sea Surface Height Derived from TOPEX Altimeter Data," R. Glazman, A. Fabrikant and A. Greysukh.

9. "Altimetric Measurements of Westward Propagation in the World Oceans," M. Schlax, D. Chelton and R. Matano.

10. "Comparison of TOPEX/POSEIDON Altimetry Observations to an Eddy-Resolving Ocean General Circulation Model," L.-L. Fu, R. D. Smith and R. C. Malone.

11. "Towards Estimating Global Ocean Circulation from TOPEX/POSEIDON Altimeter Observations," I. Fukumori, L.-L. Fu, R. Raghunath and Y. Chao.

******* ORAL SESSION II *******

Co-Chairs:

C. Koblinsky
NASA Goddard Space Flight Center
Greenbelt, MD 20771
tel: 301-286-4718

J-F. Minster
Centre National d'Etudes Spatiales
18 Ave. Edouard Belin
1055 Toulouse Cedex
France

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1. "Mesoscale and Large-Scale Variability in the North Atlantic," D. Chelton.

2. "Analysis of the Effects of Changes in Gulf Stream Transport and Position on the North Atlantic Current Using TOPEX/POSEIDON Altimeter Data," S. Singh and K. A. Kelly.

3. "Propagations in the Gulf Stream Region During 1993 As Seen By TOPEX/POSEIDON and a Numerical Model," P. Rogel, J.-F. Minster, E. Blayo, M. England, J. Verron and C. Ybert.

4. "Zonal and Meridional Gradients of Sea Surface Elevation in the Tropical Atlantic," E. J. Katz.

5. "Large-Scale Circulation in the South Indian Ocean from TOPEX/POSEIDON Altimetry," Y. H. Park and L. Gamberoni.

6. "Tracking Brazil current rings across the South Atlantic," K. Heywood

7. "Context for the Hawaiian Ocean Time series Measurements from TOPEX/POSEIDON," G. T. Mitchum, R. Lukas, B. Qiu and A. J. Busalacchi.

8. "The Pacific Ocean Circulation from TOPEX/POSEIDON Data and a General Circulation Model," D. Stammer and C. Wunsch.

9. "Resolution of the Winter Circulation in the California Current System Using TOPEX/POSEIDON and AVHRR Data," P. T. Strub.

10. "Variability in Equatorial Pacific Sea Surface Topography During the Verification Phase of the TOPEX/POSEIDON Mission," J. Busalacchi, J. McPhaden and J. Picaut.

11. "Combining TOPEX/POSEIDON Altimeter Data with Oceanographic Data to Estimate the Transport of the Kuroshio South of Japan," S. Imawaki and H. Uchida.

12. "Variations of the Oceanic Currents Observed by the TOPEX/POSEIDON Altimeter in the Western North Pacific," H. Kawamura, O. Isguchi and Y. Sawa.

13. "Validation of a Marine Geoid Synthesized from Satellite Altimetry and a Primitive Equation Ocean Model," D. Engelhardt, G. Born and G. Jacobs.

******* ORAL SESSION III *******

Co-Chairs:

C. Le Provost
Institut de Mecanique de Grenoble
B.P. 53X, 38041 Grenoble Cedex
France
Tel: 33 76 82 50 65

V. Zlotnicki
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena,CA 91109
tel: 818-354-5519

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1. "Variations of the Mean Sea Level as Observed by TOPEX/POSEIDON," J.-F. Minster, C. Brossier and P. Rogel.

2. "Observing Mean Sea Level Variations Using TOPEX/POSEIDON Altimetry," C.-K. Shum, B. D. Tapley, J. C. Ries and M. Guman.

3. "Global Sea Level Change from Altimetry," C. Wagner, B. Cheney, L. Miller, and C. K. Tai.

4. "Mean Sea Level Variations in the Mediterranean Sea From Two Years of TOPEX/POSEIDON Data," G. Larnicol, P. Y. Le Traon, P. De Mey.

5. "Relation Between Sea Level and Barometric Pressure Determined from Altimetric Data," P. Gaspar and R. Ponte.

6. "Intercomparison of Recent Ocean Tide Models," O. B. Andersen, P. L. Woodworth and R. A. Flather.

7. "TPXO.2: An Eight Constituent Inverse Solution for Global Ocean Tides," G.D. Egbert, A.F. Bennett, and M.G.G. Foreman

8. "Another Ocean Tide Model Derived from TOPEX/POSEIDON Satellite Altimetry," S. D. Desai and J. M. Wahr.

9. "Tides and Altimetry in Marginal and Semi-Enclosed Seas," L. H. Kantha, P. E. Pontius and D. M. Beitzell.

10. "Some Geodetic Applications of the New TOPEX/POSEIDON Oceanic Tide Models," R. D. Ray, B. F. Chao, B. V. Sanchez and R. S. Nerem.

11. "Observations of Spatial and Temporal Geographically Correlated Orbit Errors for TOPEX/POSEIDON Using the Global Positioning System," E. J. Christensen, J. R. Guinn, B. J. Haines and R. A. Norman.

12. "The Spatial and Temporal Characteristics of TOPEX/POSEIDON Radial Orbit Error," A. Marshall

******* POSTER SESSION *******

Co-Chairs:

P. Woodworth
Proudman Oceanographic Laboratory
Merseyside L43 7RA
U.K.
tel: 44 51 653 8633

C.-K. Shum
Center for Space Research
University of Texas at Austin
Austin, TX 78712
tel: 512-471-5573

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1. "Seasonal Sea Level Changes from the TOPEX Altimeter," M.C. Naeije, P.N.A.M. Visser, and K.F. Wakker.

2. "Sea Level Variability from a Global Isopycnal Ocean General Circulation Model," D. Hu, Y. Chao and L.-L. Fu.

3. "Near-Real Time Assimilation of TOPEX/POSEIDON and ERS-1 Data into the French Navy's SOAP-93 Forecasting System," E. Dombrowsky, P. Bahurel and P. Le Traon.

4. "Open-Ocean Validation of TOPEX/POSEIDON Sea Level in the Western Pacific," L. Gourdeau, J. Picaut, T. Busalacchi, E. Hackert, Gonzales and J. McPhaden.

5. "Seasonal Variability of Western Pacific Equatorial Currents Inferred from Satellite Altimetry and Drifting Buoy Trajectories," Y. Yu, W. Emery and R. Leben.

6. "Applications of TOPEX/POSEIDON Altimeter and AVHRR IR Data to Studies of Variability in the Tropical Pacific Ocean," X.-H. Yan and O. Zheng.

7. "Sea Surface Dynamic Height in the Pacific Ocean from TOPEX Altimetry Data," T. Kuragano and A. Shibata.

8. "A Comparison Between Altimetric Sea Surface Height and Oceanogrphic Data South of Japan," H. Nishida, Y. Michida, B.Kinoshita, Y. Ganeko. H. Yoritaka and T. Kanazawa.

9. "Low Frequency Variability in the Kuroshio Extension and Gulf Stream Observed by TOPEX/POSEIDON Altimetry," L. Wang and C. Koblinsky.

10. "Sythesis of TOPEX/POSEIDON and ERS-1 Altimeter Data with Satellite-Tracked Drifter Trajectories in the North Pacific and Bering Sea," C.A. Fox, R.R. Leben, P.J. Stabeno

11. "Variability of the North Atlantic Current: Inferred from Satellite Altimetry and Subsurface Drifter Data," C. Modell and M. Prater.

12. "The Structure and the Annual Cycle of the Guinea Dome," O. Gnade.

13. "Using TOPEX/POSEIDON Data in the Tropical Atlantic Ocean," S. Arnault, J. C. Thil and Y. Menard.

14. "Assimilation of Altimetric Data Into a Circulation Model of the Gulf of Mexico," J.–K. Choi and L. H. Kantha.

15. "Seasonal Variation of the Mean Sea Surface in the Mediterranean Sea," P. Bonnefond, P. Exertier, F. Barlier and S. Bruinsma.

16. "Circulation of the Western Mediterranean from Satellite Altimetry using ERS-1 and TOPEX/POSEIDON Data," J. Vazquez and J. Font

17. "Combination of TOPEX/POSEIDON Data and ERS1 Data to Observe the Oceanic Circulation," P. Y. Le Traon and P. Gaspar.

18. "AVISO: Keeps on Going," P. Vincent, F. Blanc, P. Le Traon and P. Gaspar.

19. "Ocean Tide Model Obtained from TOPEX/POSEIDON on Altimetry Data," K. Matsumoto, M. Ooe, T. Sato and J. Segawa.

20. "Tidal Analysis of TOPEX/POSEIDON Altimetry," E. J. O. Schrama and R. D. Ray.

21. "TOPEX/POSEIDON Tides: The OMP2 Atlas," P. Mazzega, M. Berge and O. Francis.

22. "Wave Fields Improvement by Re-Analysis of Model Outputs with Satellite Measurements," J. Barckicke and Y. Menard

23. "The Characteristics of Hurricanes From TOPEX/POSEIDON Altimetry," C. S. Morris, W. H. Daffer and P. S. Callahan.

24. "Are Internal Wave Solitons Detectable in the 10Hz TOPEX Altimetric Data?" B. A. Briggs, M. A. Coffey, L. H. Kantha, G. H. Born and R. Leben.

25. "TOPEX/POSEIDON Dynamic Tracking and Gravity Field Model Turning Using GPS, DORIS and Laser Measurements," F. Perosanz, G. Balmino, J. C. Marty, R. Biancale, J. M. Lemoine and B. Moynot.

26. "Presentation of the Final State of the GRIM4 Earth Gravity Field Mode, GRIM4-S4," R. Biancale, G. Balmino, J. C. Marty, B. Moynot, P.Schwintzer, C. Reigber, A. Bode, H. Massmann and J. C. Raimondo.

27. "Origin and Orientation Variations of the Terrestrial Frame Observed from LAGEOS," E. Pavlis

28. "Assessment of the TOPEX Altimeter Bias and Slope Using Sensor Data Records," R. Kolenkiewicz and C.F. Martin

Appendix D

Papers Submitted to the Second TOPEX/POSEIDON JGR Special Issue (as of 15 February, 1995)

Appendix D

Papers Submitted to the Second TOPEX/POSEIDON JGR Special Issue (as of 15 February, 1995)

JGR-735 Grundlingh, M.,
"TOPEX/POSEIDON tracks eddies in the southeast Atlantic and southwest Indian Oceans"

JGR-738 Queffeulou, et al.,
"Validation of ERS-1 and TOPEX/POSEIDON altimeter wind and wave measurements"

JGR-744 Nerem,
"Prospects for measuring global mean sea level variations using TOPEX/POSEIDON altimeter data."

JGR-745 Marshall et al.,
"The temporal and spatial characteristis of TOPEX/POSEIDON radial orbit error"

JGR-749 Sanchez & Pavlis,
"The estimation of main tidal constituents from TOPEX/POSEIDON altimetry data using a Proudman Function Expansion."

JGR-750 Sanchez, Cunningham, & Pavlis,
"The calculation of the dynamic sea surface topography and the associated flow field from TOPEX/POSEIDON altimetry data: A new method."

JGR-751 Minster, Brossier, & Rogel,
"Variation of the mean sea level from TOPEX/POSEIDON data."

JGR-753 Bonnefond, Exertier, Schaeffer & Barlier,
"First results of the TOPEX/POSEIDON validation in the Mediterranean area"

JGR-760 Wunsch and Stammer,
"The global frequency-wave number spectrum of oceanic variability estimated from TOPEX/POSEIDON altimetric measurements."

JGR-761 Andersen, Woodworth and Flather,
"Intercomparison of recent ocean tide models: - preliminary investigations of recent global ocean tide models with main attention to the Atlantic Ocean and Atlantic shelf regions"

JGR-762 Blomenhofer and Hein,
"Sea level monitoring at Lampedusa for the TOPEX/POSEIDON altimeters calibration using GPS in buoys"

JGR-763 Fukumori,
"Assimilation of TOPEX sea level measurements with a reduced-gravity shallow water model of the tropical Pacific Ocean."

JGR-764 Visser, Ambrosius and Wakker,

"A fast technique for gravity field parameter estimation from TOPEX/POSEIDON GPS SST data"

JGR-765 Matsumoto, Ooe, Sato, Segawa,
"Ocean tide model obtained from TOPEX/POSEIDON altimetry data"

JGR-766 Picaut, Busalacchi, McPhaden, Gourdeau, Gonzalez, Hackert,
"Open-ocean validation of TOPEX/POSEIDON sea level in the western equatorial Pacific"

JGR-767 Birkett,
"An assessment of the performance of the TOPEX/POSEIDON radar altimeter in monitoring the changing layers of climatically sensitive lakes."

JGR-768 Ali & Sharma,
"Importance of reference surface in sea level studies from TOPEX."

JGR-769 Verstraete & Park (OLD JGR 713),
"Comparison of TOPEX/POSEIDON altimetry and in situ sea level data at Sao Tome Island, Gulf of Guinea."

JGR-770 Chao and Fu,
"Sea level variability over the World Ocean during 1992-93."

JGR-771 Fu and Davidson,
"A note on the barotropic response of sea level to time-dependent wind forcing."

JGR-772 White and Heywood,
"Seasonal and interannual changes in the North Atlantic subpolar gyre from Geosat and TOPEX/POSEIDON altimetry"

JGR-773 Yu, Emery and Lebon,
"An annual cycle of geostrophic currents in the western tropical Pacific from satellite altimeter observations."

JGR-774 Cooper and Forristall,
"On the use of satellite wave data to estimate extreme wave heights"

JGR-775 Quartly, Guymer and Srokosz,
"The effects of rain on TOPEX radar altimeter data"

JGR-776 Glazman, Fabrikant and Greysukh,
"Statistics of spatio-temporal variations of sea surface height based on TOPEX altimeter measurements."

JGR-777 Kantha,
"Barotropic tides in the global oceans from a nonlinear tidal model assimilating altimetric tides Part I: Model description and results"

Appendix E

List of Attendees

Appendix E

Attendees

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15. Supplementary Notes

16. Abstract

This third TOPEX/POSEIDON Science Working Team meeting was held on December 4, 1994 to review progress in defining ocean tide models, precision Earth orbits, and various science algorithms. A related workshop on ocean tides convened to select the best models to be used by scientists in the Geophysical Data Records.

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